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JOURNAL of PALEONTOLOGY

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FUSULINIDS FROM THE LOWER PENNSYLVANIAN ATOKA AND BOGGY FORMATIONS OF OKLAHOMA

M. L. THOMPSON
State University of Iowa, Iowa City, Iowa

ABSTRACT

The Lower Pennsylvanian Atoka formation of Oklahoma contains one of the oldest fusulinid faunas known, and the fauna of the Boggy formation is only slightly younger. Representatives of the fusulinid genera *Staffella*, *Fusulinella*, and possibly *Wedekindellina* occur in both of these formations, and *Fusulina* s. s: is represented in the Boggy. In this paper the genus *Fusulinella* is discussed at some length and its limits are redefined; five species of *Fusulinella*, one of *Wedekindellina*, and one of *Fusulina* s. s. are described and illustrated; and two species of *Staffella* and two poorly preserved representatives of *Fusulina* s. s. are discussed. Four of the species of *Fusulinella* are new.

Although fusulinids are very abundant in the Middle and Upper Pennsylvanian and the Permian rocks of North America, they are relatively rare in the lower more clastic phases of the Pennsylvanian, and hence very little is known concerning the early history of this group in America. The numerous well-preserved specimens on which this study is based were obtained from seven localities and five horizons in the Atoka and Boggy formations of Coal and Pontotoc counties, Oklahoma, and they were gleaned from numerous samples of microfossils which were collected by Mr. R. V. Hollingsworth in southern Oklahoma. The writer wishes to take this opportunity to acknowledge his indebtedness to Dr. A. K. Miller for his continued interest and many valuable criticisms, and to Mr. R. V. Hollingsworth for granting him permission to study this material.

THE ATOKA AND BOGGY FORMATIONS

The relative age of the basal Pennsylvanian formations in the different Carboniferous basins in southern Oklahoma and adjacent portions of Arkansas and Texas, as well as the age of contemporaneous formations outside this area, is more or less a moot question. However, it is generally agreed that the earliest Pennsylvanian seas of the Mid-Continent region occupied the basins of the southern Oklahoma province, and that the lowest Pennsylvanian beds found there contain some of the oldest known Pennsylvanian faunas.

Typically the Atoka formation consists of something over 3,000 feet of shale, thin sandstones, and thin calcareous beds. Its type locality is at Atoka, Oklahoma, but it outcrops to the north of there in Coal County, Oklahoma, and to the northeast in Arkansas. It is underlain by the

Wapanucka formation, which is composed of limestone with some shale and sandstone, and which is generally regarded as the oldest Pennsylvanian formation of this region. The Hartshorne sandstone, also of Lower Pennsylvanian age, overlies the Atoka.

Various workers have at one time or another correlated the Atoka with strata of quite disparate age. These correlations were based on lithologic and structural evidence and on megascopic fossils, including cephalopods, gastropods, pelecypods, brachiopods, and corals. Although at a very few horizons micro- and macro-fossils are fairly abundant, for the most part the Atoka is rather sparsely fossiliferous, and some of the largest collections which have been used in correlating it consisted entirely of molds and casts and are admittedly not very satisfactory for precise work.

It is now more or less generally recognized that the Wapanucka is of Morrow age and that the Atoka is either upper Morrow or slightly younger than the Morrow. However, in so far as I am aware, no fusulinids have been reported from the Morrow, and only two very small forms have been described from the Wapanucka; these were referred by Galloway and Harlton (4)[1] to the genus *Orobias*, but I am inclined to doubt that they are fusulinids and they do not seem to me to be at all similar to the genotype of *Orobias*.

In 1931 Skinner (16, pp. 255–256, pl. 30, figs. 7–9, 11) and Thomas (19, pp. 31–32, pl. 1, figs. 1–7) described two species of *Fusulinella* from the Marble Falls formation (Bend) of Mason County, Texas. Plummer added to Thomas's paper a note concerning the associated fauna in which he stated that eleven of the twelve species of cephalopods, gastropods, brachiopods, bryozoans, and corals which occur within the fusulinid zones of the Marble Falls are to be found also in the Morrow of Arkansas. A detailed comparison of *Fusulinella fittsi* Thompson, n. sp., from about 100 feet above the base of the Atoka of Coal County, Oklahoma, with *Fusulinella primaeva* (Skinner) and *Fusulinella llanoensis* (Thomas) of the Marble Falls formation of Mason County, Texas, indicates that the Atoka species is more primitive than are those known from the Marble Falls formation. The Atoka form, which is found associated with a primitive species of *Staffella*, *S. atokensis* Thompson, indicates that at least the lower 100 feet of the Atoka formation at this locality may be even older than that part of the Marble Falls formation from which Skinner and Thomas obtained their specimens. However, the distribution of fusulinids in these horizons is as yet not sufficiently well known to warrant definite conclusions in regard to their relative ages.[2]

[1] Numbers refer to bibliography at end of paper.

[2] R. C. Moore advises that the lower part of beds classed as Atoka in Coal County, Oklahoma, are of Morrow age. The lithologic, faunal and stratigraphic relationships of these beds indicate that they should be allied with the Wapanucka rather than Atoka deposits. He reports that in the Ardmore Basin, south of the Arbuckles, fusulinids first appear in the Bostwick limestone of Morrow and Bend age, several hundred feet below the lowest beds containing Des Moines fossils.

A fusulinid species from about 200 feet above the base of the Atoka formation, which I am describing below as *Fusulinella prolifica*, is clearly less primitive than *F. fittsi*, and it is about as far advanced biologically as are *F. primaeva* and *F. llanoensis*. The beds in which it occurs are probably not greatly different in age from the Marble Falls formation of Texas.

The Boggy formation occurs in the same general region of Oklahoma as the Atoka. It consists largely of shale, some sandstone, and a few beds of limestone, and it is typically some 2,000 or 3,000 feet thick. It is separated from the underlying Atoka formation by the Hartshorne sandstone, the McAlester shale, and the Savanna sandstone, which together aggregate over 3,000 feet in thickness. A rather large collection of fusulinids from the south bank of Bois d'Arc Creek in Pontotoc County, Oklahoma (at or near Morgan's "Locality 93") (11, p. 241), contains the following fusulinid species: *Staffella hollingsworthi* Thompson, *Fusulinella gallowayi* (Skinner), *Fusulinella trisulcata* Thompson, n. sp., *Wedekindellina euthysepta* (Henbest)?, and *Fusulina leei* Skinner. The beds in which these forms occur are stated by Morgan (11, p. 241) to be in the upper portion of the Boggy formation. The position of these species in the evolutionary series of the fusulinids seems to me to indicate that this horizon is very closely similar in age to the fusulinid-bearing beds of the Cherokee shale immediately above the Bluejacket sandstone of Mayes County, Oklahoma, and to that part of the Cherokee of Iowa which lies 30 to 60 feet below the White Breast coal and contains many fusulinids.

COMPARISONS WITH OTHER FUSULINID FAUNAS

The Atoka and Boggy formations and the intervening beds are in part, at least, equivalent in age to the Lower Pennsylvanian strata of Texas, Arkansas, the Northern Mid-Continent region, and probably the eastern portion of the United States and the Rocky Mountain region. However, with the exception of *Fusulinella llanoensis* (Thomas) and *F. primaeva* (Skinner) of the Marble Falls formation of Texas and *F. iowensis* Thompson of the basal Cherokee of Iowa, no forms comparable to the primitive fusulinids of the Atoka have been described from America. *F. iowensis* from the basal Cherokee of Iowa is very primitive, and it does not seem to be far removed biologically, and probably stratigraphically, from *F. fittsi*, described below.

Close similarities are at once evident when the Atoka and Boggy fusulinids are compared with those from the Huanglung limestone of southeastern China. Lee, Chen, and Chu (6) separated the fauna of this limestone into an upper and a lower faunule. In the lower of these faunules in the Huanglungshan they have identified the following fusulinid species: *Fusulinella obscura* (Lee and Chen), *F. lata* (Lee and Chen), *F. bocki* Möller, *F. parva* (Lee and

Chen), *F. subrhomboides* (Lee and Chen), *F. schwagerinoides* (Deprat), and "*Staffella angulata* (Colani)." The species listed last is the genotype of *Ozawainella*, but I doubt that the identification is correct. In the upper faunule in the same general region they have identified *Fusulina fava* (Lee and Chen), *Fusulinella schwagerinoides* (Deprat), *F. bocki* Möller, and "*Staffella angulata* (Colani)." These authors have noted that in every locality the genus *Fusulina* s. s. makes its first appearance in the Huanglung limestone in the upper faunule, and they state that the lower faunule is characterized by the absence of species of this genus and by the presence of numerous individuals of minute fusulinids such as *Fusiella*, *Fusulinella*, and *Schubertella*. I am tentatively regarding *Schubertella* as a synonym of *Fusulinella*. The oldest representative of *Fusulina* s. s. in the collections I am studying from Oklahoma came from the basal portion of the Boggy formation, and at that horizon specimens of this genus are very rare and are very primitive. In 1930 Roth (14) listed *Fusulinella meeki* and *Fusulinella meeki tregoensis* from "about 500 feet below top" of the Atoka formation near Red Oak, Latimer County, Oklahoma. Both of these species are referable to the genus *Fusulina* s. s., but I am inclined to doubt the correctness of the identification, for Galloway and Ryniker (5) have described and illustrated some fusulinids from the same horizon and the same general locality and they represent primitive genera (*Staffella*,[3] *Fusulinella*, and *Wedekindellina*?) and not *Fusulina* s. s.

The fusulinid species of the lower Atoka formation which are comparable to those of the lower faunule of the Huanglung limestone are *Staffella atokensis* Thompson, *Fusulinella fittsi* Thompson, n. sp., *F. oliviformis* Thompson, n. sp., and *F. prolifica* Thompson, n. sp. The fusulinid fauna of the Boggy formation seems to correspond more closely with that of the upper faunule of the Huanglung limestone and it contains the following species: *Staffella hollingsworthi* Thompson, *Fusulinella gallowayi* (Skinner), *F. trisulcata* Thompson, n. sp., *Wedekindellina euthysepta* (Henbest)?, and *Fusulina leei* Skinner. As mentioned above, Galloway and Ryniker (5) have described as *Staffella mölleri* Ozawa, *Schubertella transitoria* Staff and Wedekind, and *Fusulinella euthysepta* Henbest three species of fusulinids from about 500 feet below the top of the Atoka formation near Red Oak, Latimer County, Oklahoma. I do not have specimens from this horizon or locality and hence I cannot express a definite opinion as to the affinites of these forms, but the form that they identified as *Schubertella transitoria* may be conspecific with the specimens I am describing below as *Fusulinella oliviformis* Thompson, n. sp.

[3] The stratigraphic range of this genus is not well known. It is possible (but not probable) that the forms from the Upper Permian of southwestern Texas that in 1908 Girty (*U.S. Geol. Survey, Prof. Paper* 58, pp. 65–67, pl. 5, fig. 6, pl. 27, fig. 5) described as *Fusulinella* sp. a, *F.* sp. b., and *F.* sp. c, may represent this genus. I inadvertently failed to mention these forms in my discussion of *Staffella* on pages 111–120 of this volume.

Genus FUSULINELLA Möller

The genus *Fusulinella* was established by Möller (9) in 1877 but no specific representative of it was named at this time. However, a year later Möller (10) referred four species to it in the following order: *Fusulinella bocki* Möller, the genotype (established by Douvillé, 3, p. 584); "*Fusulinella*" *sphaeroidea* (Ehrenberg); "*Fusulinella*" *bradyi* Möller; and "*Fusulinella sphaerica* (Abich)". Subsequent to Möller's work and prior to 1925, most paleontologists applied the name *Fusulinella* to only the spheroidal and lenticular type of fusulinids that are somewhat similar to the last three species listed above, and during this time it was not applied to any forms that are closely similar to (congeneric with) the genotype. This usage of the name *Fusulinella* is clearly demonstrated in the works of Schwager (15), Lienau (7), Lörenthey (8), Douvillé (3), Staff (17), Deprat (2), Ozawa (12), and others. Staff in 1909 and Deprat in 1913 definitely excluded from this genus forms that are now regarded as being congeneric with the genotype. However, in 1925 Ozawa (13) took cognizance of this error and correctly restricted the genus to forms that are congeneric with *Fusulinella bocki*, the genotype. At this same time Ozawa (13, p. 24) established the genus *Staffella* for the lenticular and spheroidal forms which had been included in the genus *Fusulinella* by other workers, and he designated "*Fusulinella sphaerica* Möller" [= *Staffella moellerana* Thompson] as the genotype of *Staffella*.

In 1910 Staff and Wedekind (18) established the genus *Schubertella* for a small species of fusulinid, *S. transitoria* Staff and Wedekind from Spitzbergen, which they considered of special interest "*weil sie von Fusulinella zu Schellwienia überleitet.*" They regarded this genus as including fusulinids in which the axis of coiling is the largest diameter, the spirotheca is composed of only a tectum, the inner volutions are endothyroid, and the septa are weakly fluted. However, their illustrations (two drawings of axial sections) show clearly that the inner volutions of the type species of this genus are not truly endothyroid, and they also show that the chomata of this genotype are not greatly different from those of the genotype of *Fusulinella*. Furthermore, many forms similar to their genotype are now known from America and in all of them the spirotheca is precisely like that of the genotype of *Fusulinella* and is not composed of only a tectum. I am, therefore, inclined to believe that Staff and Wedekind misinterpreted the spirothecal structure of *Schubertella transitoria* and that this species is in reality referable to *Fusulinella*. It seems to me, therefore, that *Schubertella* should be suppressed as a synonym of *Fusulinella*, which has priority.

I recently suggested (20) that the genera *Neofusulinella* Deprat and *Depratella* Ozawa are synonymous with *Schubertella* Staff and Wedekind. In attempting to compare possible congeneric forms with the genotype of *Neofusulinella*, *N. lan-*

tenoisi Deprat, I met with considerable difficulty, as the inner volutions of this species are not clearly shown by Deprat's illustrations (drawings), and his sections probably were not centered. Colani (1) has even gone so far as to say that *N. lantenoisi* "est une espèce fictive". It seems to me that until the type specimens of this species are restudied, the genus *Neofusulinella* must remain without a clear definition. However, there does not seem to be any good reason to doubt that Deprat based his genus on specimens from Bam-na-mat, between Sam-neua and Luang-prabang; these specimens were found associated with a form which Deprat identified as *Doliolina lepida* (Schwager), and he considered them as being Permian in age. Even though the genotype of *Neofusulinella* is poorly illustrated, the suggestion exists that it is congeneric with the type species of the Permian genus *Depratella* Ozawa, and *Neofusulinella* has priority. The genotype of *Yangchienia* Lee, *Y. iniqua* Lee, now appears to me to be generically distinct from the type species of *Neofusulinella*.

If, as was stated by Ozawa, the spirotheca of *Depratella giraudi* (Deprat), the genotype of *Depratella* Ozawa, does not have layers of tectoria, that form is definitely not congeneric with the American forms (previously referred to *Schubertella*) which I am referring to the genus *Fusulinella*.

In 1930 Galloway and Ryniker (5, pp. 23–24, pl. 5, figs. 1–5) described and illustrated a form from the upper portion of the Atoka formation of Latimer County, Oklahoma, as *Schubertella transitoria* Staff and Wedekind. In two of the collections which I am studying from about 200 feet above the base of the Atoka formation of Coal County, Oklahoma, there is a large number of small fusulinids which may be conspecific with Galloway and Ryniker's specimens. My specimens have a spirothecal structure typical of the genus *Fusulinella* and I am describing them below as *Fusulinella oliviformis* Thompson, n. sp. I also have specimens from the upper portion of the Boggy formation of Pontotoc County, Oklahoma, which are clearly conspecific with *Schubertella gallowayi* Skinner, originally described from the middle Cherokee of Mayes County, Oklahoma. These specimens also have a spirothecal structure like that of typical *Fusulinella*, and I am accordingly referring them to that genus.

In 1930 Lee and Chen (6) referred some small fusulinids from the Huanglung limestone of southeastern China to the genus *Schubertella*. They separated these forms from the genus *Fusulinella* primarily on the basis of their spirothecal structure. They described the spirotheca of this group as being composed of only one rather dense layer and pointed out that the inner volutions of many (but not all) of their specimens are at an angle to the outer fusiform volutions. Although I have not had an opportunity to study any of the forms from the Orient formerly referred to *Schubertella*, they seem to me to be more closely related to the genotype

of *Fusulinella* than to any other genotype and I am, therefore, referring them to that genus—they may, however, represent an unnamed genus.

It is now generally recognized that the septa and spirotheca of the genera *Fusulinella*, *Wedekindellina*, and *Fusulina* possess a similar type of structure, which is commonly referred to as the "Fusulinella" type, for Möller (9) first described and illustrated this type of structure in his original diagnosis of the genus *Fusulinella*. However, it has often been observed in representatives of these genera that the posterior portion of the anterior tectorium of the septa is very similar in density to the diaphanotheca on the opposite side of the tectum. This lighter layer is usually thinner than the diaphanotheca on the opposite side of the tectum, and it decreases in thickness toward the base of the septa. This structure has been observed in so many sections that we can safely conclude that it is not accidental. In thin well-preserved sections it seems clear that this less dense layer on the anterior side of the tectum of the septa is continuous with the lower portion of the diaphanotheca of the spirotheca of the succeeding chamber. Also, the very lowest portion of the upper tectorium of the spirotheca is very similar in density to the diaphanotheca below the tectum. I have not been able to find any section which shows clearly that this lighter portion of the upper tectorium is continuous with the diaphanotheca of the septa of the following volution.

In all of the sections that I have examined which are referable to the genera *Fusulinella*, *Wedekindellina*, and *Fusulina*, the spirotheca and the antetheca of the last chamber are composed of a tectum and a diaphanotheca. It therefore seems clear that the diaphanotheca and the tectum are the primary constituents of the spirotheca and the antetheca —the tectum is the more dense outer protecting portion. The downward extension of the diaphanotheca on the anterior side of the tectum of the septa, and possibly its presence on the tectum of the spirotheca of the preceding volution, suggests that the lower portion of the diaphanotheca of the spirotheca and the antetheca forms a more or less complete lining of the entire chamber which was secreted at the same time as the spirotheca and antetheca. In 1931 Skinner (16) studied the septa of *Fusulina* s. s. from Oklahoma and Colorado and observed a structure somewhat similar to that described above. However, in his diagrammatic sketch of the structure of the septa of these forms he shows secondary material between the posterior diaphanotheca and the tectum as well as between the anterior diaphanotheca and the tectum. Skinner stated that the diaphanotheca was formed later than the tectum, but my observations do not bear out this statement.

In the following descriptions of species of *Fusulinella*, *Wedekindellina*, and *Fusulina*, I am designating the less dense layer on the anterior side of the tectum of the septa as the anterior

diaphanotheca, but I am regarding the less dense layer immediately over the tectum of the spirotheca as a portion of the upper tectorium.

SYSTEMATIC DESCRIPTIONS

FUSULINELLA GALLOWAYI (Skinner)

Plate 26, figures 7–9

Schubertella gallowayi SKINNER, *1931*, Jour. Paleontology, vol. 5, pp. 256–257, pl. 30, figs. 1, 5, 5*a*.

Skinner established this species in 1931, basing it on specimens from a marl immediately above the Bluejacket sandstone (Cherokee) of Mayes County, Oklahoma. He illustrated an axial section of the holotype and a sagittal section of a paratype. One of the collections which I am studying from strata on the south bank of Bois d'Arc Creek, Pontotoc County, Oklahoma, (Morgan's "Locality 93") (11, p. 241) which Morgan considered to be upper Boggy, contains a large number of specimens which are undoubtedly conspecific with Skinner's type specimens.

Most of the essentials of this species have been described by Skinner, and since his publication is readily available to most paleontologists there seems to be no need to duplicate his work. However, my observations on the structure of the spirotheca and several other characters differ considerably from those recorded by Skinner, and hence a part of the description of the species will be given here for the sake of clearness.

Shell minute, and subglobular. Mature forms consist of four volutions and are 0.85 to 0.95 mm. in length and up to 0.65 mm. in width. The form ratio is about 1:1.3. The septal count varies considerably with different specimens and it gives 7 to 11 septa for the first volution, 10 to 17 for the second volution, 14 to 20 for the third volution, and 17 to 18 for the fourth volution.

Contrary to Skinner's observations that the spirotheca is composed of only two outer layers of tectoria and a tectum, my specimens show clearly that the spirotheca is composed of the same four layers that are present in all unquestionable representatives of this genus. Near the center of the tunnel of the third volution the upper tectorium is 7.0 microns thick, the diaphanotheca is 5.3 microns thick, and the lower tectorium is 7.8 microns thick. The septa are composed of five layers as is typical of the genus *Fusulinella*. In his original description of this species Skinner stated that the axis of the "nucleoconch" (juvenarium) was oblique to the axis of the outer volutions. However, even though the intersection of the tunnel with axial sections is slightly irregular in some of the inner volutions, the juve-

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EXPLANATION OF PLATE 26

All of the specimens illustrated on this plate came from the Atoka and Boggy formations of Coal and Pontotoc counties, Oklahoma. All illustrations are unretouched photographs.

FIGS. 1–6—*Fusulinella fittsi* Thompson, n. sp. 1, 3, 5, Axial sections, ×40; 2, sagittal section, ×40; 4, 6, external views, ×20. Univ. Iowa, 807–811. (p. 300).

7–9—*Fusulinella gallowayi* (Skinner). 7, Sagittal section, ×40; 8, external view, ×20; 9, axial section, ×40. Univ. Iowa, 822–824. (p. 298).

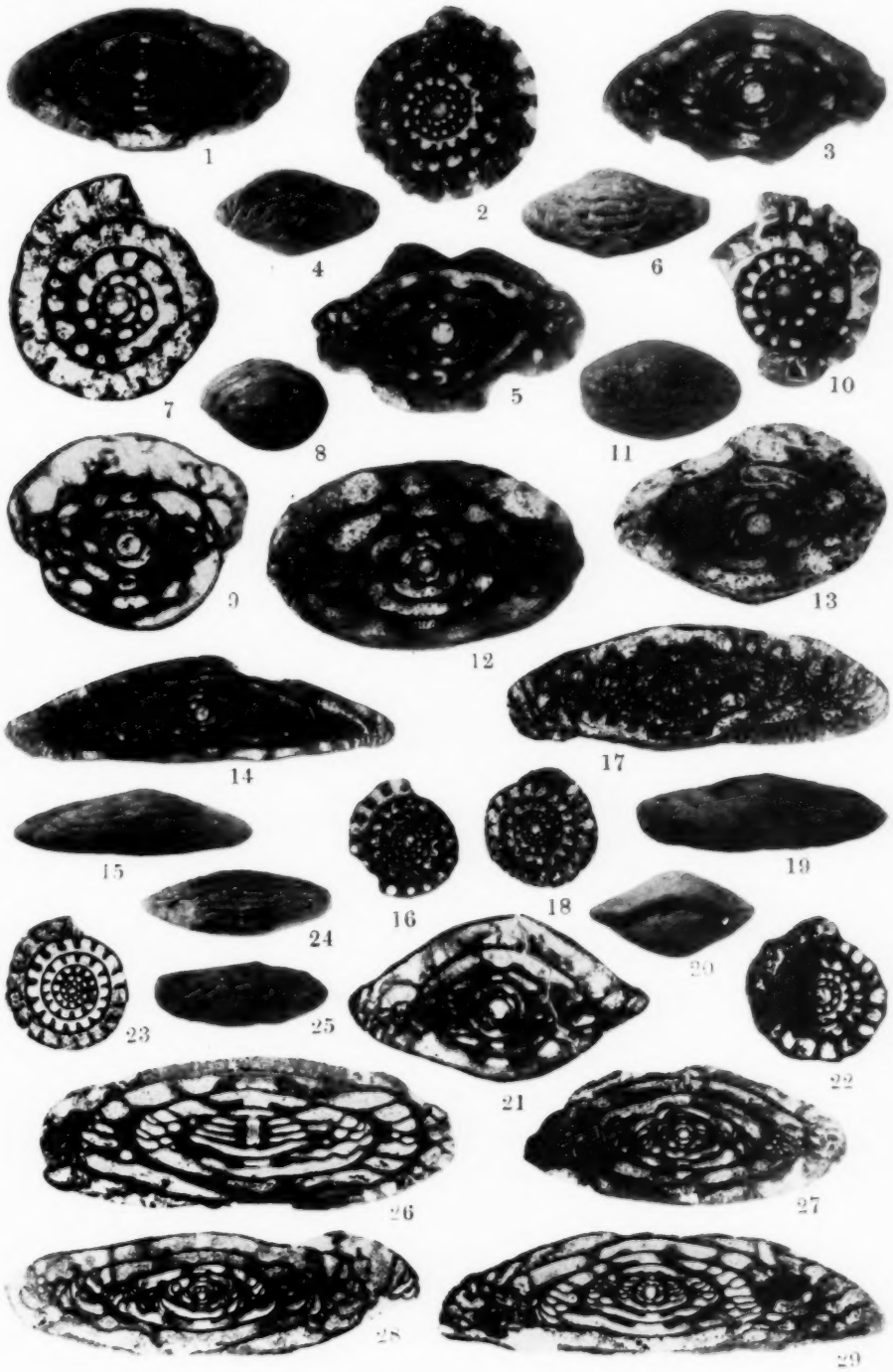
10–13—*Fusulinella oliviformis* Thompson, n. sp. 10, Sagittal section, ×40; 11, external view, ×20; 12, 13, axial sections, ×40. Univ. Iowa, 816–819. (p. 299).

14–16—*Wedekindellina euthysepta* (Henbest)? 14, Axial section, ×40; 15, external view, ×20; 16, sagittal section, ×40. Univ. Iowa, 1016–1019. (p. 304).

17–19—*Fusulina leei* Skinner. 17, Axial section, ×20; 18, sagittal section, ×20; 19, external view, ×10. Univ. Iowa, 1020–1022. (p. 305).

20–22—*Fusulinella trisulcata* Thompson, n. sp. 20, External view, ×20; 21, axial section, ×40; 22, sagittal section, ×40. Univ. Iowa, 1011–1013. (p. 303).

23–29—*Fusulinella prolifica* Thompson, n. sp. 23, Sagittal section, ×20; 24, 25, external views, ×10; 26, tangential section, ×20; 27–29, axial sections, ×20. Univ. Iowa, 1001–1006. (p. 302).



Thompson, Pennsylvanian Fusulinids

narium does not seem to me to be more oblique to the outer volutions than is that in many unquestionable representatives of *Fusulinella*, as well as many unquestionable representatives of the genera *Fusulina* s. s. and *Wedekindellina*.

The chomata of this species are well developed and they are very asymmetrical. They are about one-half the height of the chambers in the third volution and about one-third the height of the chambers in the fourth volution. The chomata reach almost to the poles. The inside diameter of the proloculum measures about 85 microns.

Fusulinella gallowayi is so distinct from all other known representatives of the genus *Fusulinella* that specific comparisons seem unnecessary.

The very short and wide shell and the broadly curving poles of this species suggest that it is not far removed from the genus *Staffella*. However, its chomata are not as well developed as are those of typical *Staffella* nor are the chomata as well developed as are those of typical representatives of *Fusulinella*. Even though this species occurs a considerable distance (stratigraphically) above the earliest appearance of typical representatives of the genus *Fusulinella*, it seems to represent a stock transitional from *Staffella* to *Fusulinella*, which has developed very slowly parallel with other representatives of *Fusulinella* with only a slight decrease in the development of the chomata.

Occurrence.—Representatives of this species have been obtained from the upper portion of the Boggy formation near the center of the NW. $\frac{1}{4}$ sec. 17, T. 2 S., R. 7 W., Pontotoc County, Oklahoma (Pl. 26, figs. 7–9). The type specimens came from immediately above the Bluejacket sandstone (near the middle of the Cherokee) of Mayes County, Oklahoma.

Hypotypes, Univ. Iowa, 820–824.

FUSULINELLA OLIVIFORMIS Thompson, n. sp.

Plate 26, figures 10–13

(?)*Schubertella transitoria* GALLOWAY and RYNIKER [not Staff and Wedekind], *1930*, Oklahoma Geol. Survey, Circ. 21, pp. 23–24, pl. 5, figs. 1–5.

Shell minute, short, ellipsoidal. Some specimens are very bluntly fusiform. The poles are rounded and the lateral slopes are low, giving rise to an elliptical profile. Mature forms consist of from three and one-half to four and one-half volutions and they are 0.85 to 1.06 mm. in length and 0.57 to 0.77 mm. in width. The form ratio varies considerably with different specimens, ranging from 1:1.10 to 1:1.66. The outer volutions in all sections are very similar in shape, but the inner volutions are quite variable in different specimens.

The septa are thin and in only a very few sections can all of the layers composing them be seen clearly. The tectoria are relatively thick. The bounding limits of the posterior diaphanotheca are difficult to locate and the anterior diaphanotheca is exceedingly thin. The septal count gives 7 for the first volution, 11 to 14 for the second volution, and 13 to 16 for the third volution. The septa are unfluted across the mid-portion of the shell and in the polar regions they are only very slightly if at all fluted.

The proloculum is spherical to irregular in shape and its inside diameter is 60 to 100 microns—the average size is much nearer the larger figure. In specimens with a very large proloculum there are fewer volutions for equal-size mature forms than in those specimens with a smaller proloculum; however, the specimens with a small proloculum have essentially symmetrical early volutions.

The spirotheca is composed of four layers, but it is very difficult to differentiate between the different layers in most of the sections. However, in well preserved sections in the fourth volution near the outer limits of the chomata, measurements show that the upper tectorium is 5.3 microns thick, the diaphanotheca is 3.5 microns thick, and the lower tectorium is 2.5 microns thick. The tectum is very thin but it is easily

seen in most of the sections. The upper tectorium increases slightly in thickness near the extreme polar regions.

The tunnel is rather high and narrow. In the fourth volution it is about two-fifths the height of the chambers and about one-third as high as wide. Its intersection with axial sections forms an essentially straight path throughout growth of the individual. The tunnel angle measures 23 to 26 degrees. The chomata are well developed and they are very asymmetrical. In the fourth volution they are about one-half the height of the chambers and are well developed for two-thirds the distance to the poles.

The form which Galloway and Ryniker described from near the top of the Atoka formation and which I am referring with question to this species differs slightly from my syntypes, and the two groups of specimens may not be conspecific. Galloway and Ryniker describe their form as having a spirotheca composed of only a tectum and a diaphanotheca. Also, they show in their drawing of an axial section that the axis of the inner volution is at an angle to the axis of the outer volutions.

The syntypes of *F. oliviformis* are over three times the size of the illustrated syntypes of *Fusulinella transitoria* (Staff and Wedekind) from Spitzbergen. Also, the shape of the shell of these two species is considerably different. *Fusulinella oliviformis* seems to be rather closely related to *F. magna* (Lee and Chen) from the basal portion of the Huanglung limestone of Chuanshan, but the American species has larger chomata and the spirothecal structure of the two forms may be different.

Occurrence.—The syntypes of this species came from approximately 200 feet above the base of the Atoka formation in the center of the line between secs. 2 and 3, T. 1 S., R. 8 E., Coal County, Oklahoma (Pl. 26, figs. 10, 12); and from the same horizon in the center of sec. 2, T. 1 S., R. 8 E., in the same county (Pl. 26, figs. 11, 13). The form described by Galloway and Ryniker, which I am referring with question to this species, came from about 500 feet below the top of the Atoka formation in Latimer County, Oklahoma.

Syntypes, Univ. Iowa, 812–819.

FUSULINELLA FITTSI Thompson, n. sp.
Plate 26, figures 1–6

Shell minute, short, obese, and uniformly fusiform. Poles bluntly to sharply pointed. External furrows very shallow and faint. Mature specimens typically consist of four to four and one-half volutions, rarely five. Mature specimens are 0.92 mm. to 1.32 mm. in length and 0.50 mm. to 0.68 mm. in width. The form ratio of mature specimens is 1:1.62 to 1:2.30, with an average of about 1:1.86.

The septa are thick and they are composed of five layers. However, the anterior diaphanotheca is so thin that it is invisible in the lower portion of the septa in most of the specimens. There are 11 septa in the first volution, 15 in the second volution, 16 to 19 in the third volution, and 18 to 21 in the fourth volution. The septa are unfluted throughout most of the shell, but rather broad fluting can be observed in the polar regions of the outer one or two volutions.

The proloculum is essentially spherical and its inside diameter measures 55 to 80 microns with an average of about 67 microns.

The spirotheca is thick. In many of the sections the diaphanotheca and the lower tectorium seem very similar and the line of demarcation is not determinable. These two layers combined are only slightly thicker than the upper tectorium and they are very similar in density to this upper layer. As a result the spirotheca appears as a homogeneous layer with a dark thin line near its center. In the fourth volution near the center of the tunnel the upper tectorium is 10.5 microns thick, the diaphanotheca is 5.3 microns thick, and the lower tectorium is 3.5 microns thick.

In the inner volutions the tunnel is very small and it is subcircular in cross section, but in the outer two volutions it becomes much wider and is about one-fifth the height of the chambers and about one-fifth as high as wide. The path of intersection of the tunnel with axial sections is irregular in the inner two volutions but it becomes more nearly straight in the outer volutions. The tunnel angle is 16 to 26 degrees in the fourth volution. The chomata are well developed and are approximately two-fifths the height of the chambers. In the inner three volutions the chomata extend with decreasing thickness from the tunnel to the poles, and they extend for over one-half the distance to the poles in the outer one or two volutions.

The spirothecal structure of *Fusulinella fittsi* agrees very closely with that of "*Fusiella*" *primaeva* Skinner of the Marble Falls formation of Texas, as illustrated by Skinner (16, pl. 30, fig. 11) in 1931. However, there seems to be little doubt that Thomas (19, p. 33) was more nearly correct in describing the spirotheca of *F. primaeva* as being of "fusulinella" type and not composed of only two outer layers of tectorium and a tectum, as is characteristic of the genus *Fusiella* Lee. My form and the Texas form resemble each other in many other respects, but a close comparison of the two species brings out several distinct differences. The Texas species is much larger at maturity, it contains more volutions, and it has a larger tunnel angle. Also, perhaps the most distinctive difference between the two species is to be found in the form of their chomata. The chomata of *F. fittsi* are much wider and are more nearly like those of *F. bocki*, whereas the chomata of *F. primaeva* are more narrow and appear to be more nearly of the type found in the genera *Fusulina* s. s. and *Triticites*.

This species resembles very closely an axial section of a small fusulinid from the basal Huanglung limestone of Shimanshan, Lungtan (southeastern China), that was figured by Lee and Chen (6, pl. 9, fig. 1) as *Fusulinella bocki* Möller. From the illustration of this section it is almost impossible to point out any difference of importance between the Chinese specimen and the types of *F. fittsi* except that the former is slightly larger. However, Lee and Chen illustrated other specimens from the same locality under the name *Fusulinella bocki* which are definitely not conspecific with *F. fittsi*. It seems probable that direct comparisons of the two forms would reveal differences which can not be discerned from the illustrations.

The very small size, the weak septal fluting, the more primitive development of the chomata and the general physiognomy of *Fusulinella fittsi* suggest to me that perhaps this species is biologically even more primitive than *Fusulinella primaeva* (Skinner) of the Marble Falls formation of Texas. There seems to be, however, some question among geologists as to the exact stratigraphic relationship between the fusulinid-bearing portion of the Marble Falls formation and the lower part of the Atoka formation, from which my specimens were collected. *Fusulinella fittsi*, which is found associated with a primitive *Staffella*, *S. atokensis*, suggests that at least the lower 100 feet of the Atoka formation at the localities listed below may be stratigraphically older than that part of the Marble Falls formation from which *Fusulinella primaeva* was described.

Occurrence.—The collections I am studying contain representatives of this species from approximately 100 feet above the base of the Atoka formation on the south bank of a small branch of Goose Creek, in the exact center of the NW. ¼ sec. 10, T. 1 N., R. 8 E., Coal County, Oklahoma (Pl. 26, figs. 2–6); and from the same horizon in the north center of sec. 19, T. 1 N., R. 8 E., in the same county (Pl. 26, fig. 1).

Syntypes, Univ. Iowa, 803–811.

FUSULINELLA PROLIFICA Thompson, n. sp.

Plate 26, figures 23–29

Shell small, elongate fusiform to subcylindrical. Lateral slopes uniform. Ends very bluntly pointed. External furrows very faint and shallow. Mature specimens consist of six to seven volutions and are 2.40 to 3.25 mm. in length and 0.85 to 1.06 mm. in width, with an average of about 2.8 mm. in length and 1.0 mm. in width. The form ratio of eight specimens is 1:2.1 to 1:2.8 for the fourth volution; 1:2.3 to 1:3.0 for the fifth volution; and 1:2.3 to 1:3.1 for the sixth volution—the averages for these volutions are 1: 2.5, 1: 2.7, and 1: 2.8 respectively.

The septa are thick and are composed of five layers. The upper part of many of the septa, immediately over the tunnel, are thickened near the top of the chambers. This extra thickening appears to be due to secondary material between the anterior diaphanotheca and the tectum. In the mid-portion of the shell the septa are essentially unfluted, but in the polar one-fourth of the outer volutions they become broadly fluted. In the inner volutions the septal fluting is much less developed and is confined to the extreme polar regions. The septal count gives 12 to 18 septa in the third volution, 14 to 20 septa in the fourth volution, and 18 to 20 septa in the fifth volution—the averages for these volutions are 14, 17, and 19, respectively.

The proloculum is essentially spherical in typical specimens and its inside diameter measures 50 to 70 microns, with an average of about 55 microns. However, the inside diameter of the proloculum of one of my specimens measures 130 microns. The inner two volutions of this species are more tightly coiled than are the outer volutions. These inner volutions are much less fusiform and are coiled more on the order of the coiling in Lower Pennsylvanian fusulinids which were previously referred to the genus *Schubertella*.

The spirotheca is thick. The lower tectorium is very thin or even absent in the region midway between the tunnel and the poles. In the center of the shell the upper tectorium is of about the same thickness as the diaphanotheca, but near the poles it is much thicker than the latter. However, the diaphanotheca and the lower less dense portion of the upper tectorium remain about equal throughout. Measurements for the layers of the spirotheca in the center of the tunnel of the fifth volution give 10.5 microns for the upper tectorium, 9.6 microns for the diaphanotheca, and 5.3 microns for the lower tectorium. About midway between the tunnel and the poles of the fifth volution these same layers measure about 17.5, 8.8, and 3.5 microns, respectively.

The tunnel is very low and broad. It is about one-tenth as high as wide and about one-fifth as high as the chambers in the sixth volution. The intersection of the tunnel with axial sections is essentially straight and the tunnel angle is 33 to 50 degrees in the sixth volution. The chomata are well developed and in the fifth volution they are about three-sevenths the height of the chambers and about one-fourth as high as wide. The tunnel-side of the chomata is very steep and poleward the slope is very gradual. The poleward limits of the chomata are not distinct and they seem to be continuous with the upper portion of the upper tectorium.

The available collections from every locality at which representatives of this species were found contain a few specimens which are particularly obese and in which the chomata are particularly well developed and extend essentially to the poles. These specimens occur in direct association with typical representatives of this species and, although I have found only a very few intermediate forms, they do not appear to differ enough to be regarded as representing a distinct species or variety. One of them is illustrated by figure 27 on plate 26.

Fusulinella prolifica has a more elongate shell, has more asymmetrical and broader chomata, and has more weakly fluted septa than *Fusulinella llanoensis* (Thomas). This species is very distinct from other described representatives of this genus.

The structure of the chomata is quite variable among the different species of this genus. In the primitive species *Fusulinella fittsi*, described above, the chomata are very strongly developed, asymmetrical, and broad. In *F. prolifica* the chomata are asymmetrical and rather broad, but they are not extensively developed as in *F. fittsi*. In the primitive species from the Marble Falls limestone of Texas, *F. llanoensis* (Thomas) and *F. primaeva* (Skinner), the chomata appear to be narrower and more nearly symmetrical. The chomata of the genotype, *F. bocki* Möller, are somewhat intermediate between these extremes, but they are more nearly like those of *F. fittsi*.

Occurrence.—This species occurs very abundantly about 200 feet above the base of the Atoka formation in the center of the section line between secs. 2 and 3, T. 1 S., R. 8 E., (Pl. 26, figs. 23–28), and in the center of sec. 2, T. 1 S., R. 8 E., (Pl. 26, fig. 29), Coal County, Oklahoma.

Syntypes, Univ. Iowa, 1001–1010.

FUSULINELLA TRISULCATA Thompson, n. sp.
Plate 26, figures 20–22

Shell minute, fusiform, short, ventricose. Lateral slopes very steep and uniform. Poles bluntly pointed. Mature forms consist of four to four and one-half volutions and are 0.78 to 0.98 mm. in length and 0.50 to 0.64 mm. in width. The form ratio of mature forms is 1:1.56 to 1:2.00. Specimens with a form ratio as small as 1:2.25 are very scarce. In some mature individuals the poles of the outer volutions are extended and are more sharply pointed, giving rise to slightly concave lateral slopes.

The septa are thick. The anterior diaphanothecae are recognizable with difficulty and are very thin in the lower portions of the septa. There are 9 septa in the first volution, 12 in the second volution, 16 in the third volution, and 19 in the fourth volution. The septa are straight and unfluted across the central one-half of the shell, but in the end zones they are broadly fluted—in mature specimens there are three furrows on each end of the antetheca which extend to the top of the antetheca.

The proloculum is spherical to irregular in shape and its inside diameter measures 65 to 75 microns. The rate of increase of the height of the septa is uniform and rapid.

The spirotheca of this species is relatively thick and is composed of four layers. Near the center of the tunnel in the fourth volution the upper tectorium is 5.0 microns thick, the diaphanotheca is 6.1 microns thick, and the lower tectorium is 2.5 microns thick. Beyond the limits of the chomata in the fourth volution these same layers measure 8.7, 4.5, and 2.5 microns, respectively. The upper tectorium decreases in thickness as the pole is approached, and the lower tectorium seems to remain rather constant throughout the length of the shell.

The tunnel is high and is rather narrow. In the fourth volution the tunnel is about one-third as high as the chambers, and it is about one-third as high as wide. The intersection of the tunnel with axial sections is irregular in the inner one or two volutions and it becomes rather straight in the remaining volutions. The chomata are well developed. They are very asymmetrical and have a very gentle slope on the poleward side. The poleward limits of the chomata are from one-half to one-third the distance from the tunnel to the poles. The tunnel angle is about 24 degrees in the fourth volution.

The axial section of *Fusulinella trisulcata* more nearly resembles that of *Fusulinella rhomboides* (Lee and Chen) than any other described species, but the septa of the latter species do not seem to be fluted as strongly as are those of *F.*

trisulcata and the spirotheca of the American form appears to be thicker. Also, *F. trisulcata* is much smaller and has fewer volutions than *F. rhomboides*. This species is found associated with *Fusulinella gallowayi*, but the two can be readily differentiated by the shape of their shells alone.

Occurrence.—This species is only known to occur in a brownish shale near the top of a hill 300 feet south of Bois d'Arc Creek, in the center of the SW. $\frac{1}{4}$ sec. 17, T. 2 N., R. 7 E., Pontotoc County, Oklahoma. Morgan (11, p. 241) stated that the strata which outcrop here are upper Boggy.

Syntypes, Univ. Iowa, 1011–1015.

Genus WEDEKINDELLINA Dunbar and Henbest

WEDEKINDELLINA EUTHYSEPTA (Henbest)?

Plate 26, figures 14–16

Fusulinella euthusepta HENBEST, *1928*, Jour. Paleontology, vol. 2, pp. 80–81, pl. 8, figs. 6–8, pl. 9, figs. 1, 2, 5.

(?) *Fusulinella euthusepta* GALLOWAY and RYNIKER, *1930*, Oklahoma Geol. Survey, Circ. 21, pp. 25–26, pl. 5, figs. 6–11. (?) ROTH, *1930*, Am. Assoc. Petroleum Geologists, Bull., vol. 14, pp. 1262, 1274.

(?) *Fusulina euthusepta* WHITE, *1932*, Texas Univ., Bull. 3211, pp. 24–25, pl. 1, figs. 1–3.

Wedekindellina euthysepta DUNBAR and HENBEST, *1933*, Cushman Lab. Foram. Research, Special Pub. no. 4, p. 134. (?), THOMPSON, *1934*, Univ. Iowa Studies Nat. Hist., vol. 16, pp. 282–285, pl. 20, figs. 1, 2, 7, 9, 12, 13, 17, 22, 24–27.

Shell very minute, elongate and slender, fusiform. Poles sharply pointed. External furrows very faint. Specimens of four and one-half volutions are 1.32 mm. in length and 0.35 mm. in width. The form ratio is 1:3.7. The axis of coiling is straight to broadly curved, and the central portion is slightly inflated.

The septa are thick and they are composed of five layers. The anterior diaphanotheca is extremely thin and indistinct. There are 8 septa in the first volution, 11 in the second volution, 14 in the third volution, and 17 in the fourth volution. The septa are unfluted but in the extreme polar regions they are irregularly folded.

The proloculum is spherical to irregular in shape and its inside diameter measures 35 to 40 microns.

The spirotheca is relatively thick. In the fourth volution in the center of the tunnel the upper tectorium is 5.3 microns thick, the diaphanotheca is 6.1 microns thick, and the lower tectorium is 3.5 microns thick. Beyond the chomata the lower tectorium is exceedingly thin or even absent. The upper tectorium, combined with the tectoria of the septa, completely fills the chambers in the extreme polar regions.

The intersection of the tunnel with axial sections is irregular and the tunnel angle measures about 23 degrees in the fifth volution. The tunnel is low and rather broad in the outer volutions where it is about two-sevenths the height of the chambers and about one-fourth as high as wide. The chomata are well developed, they are very asymmetrical, and they are about one-half the height of the chambers in the fifth volution.

The above description is based on a rather small number of specimens which may be immature. They are being referred with question to this species, for a sufficient amount of material is not at hand to make a positive identification. These specimens resemble rather closely the inner four or five volutions of the second group of specimens from the Des Moines series of Iowa which I referred in 1934 with question to *W. euthysepta*. However, if further collecting in this region proves that the specimens which I am here described and illustrating are mature forms they should be regarded as a distinct species.

Occurrence.—The specimens on which the above description is based came from above and below a 4-inch limestone on the south bank of Bois d'Arc Creek in the center of the SW.$\frac{1}{4}$ NE.$\frac{1}{4}$ NE.$\frac{1}{4}$ sec. 17, T. 2 N., R. 7 E., Pontotoc County, Oklahoma (Pl. 26, figs. 14–16). Morgan (*op. cit.*, p. 241) considered this horizon

to be upper Boggy. The syntypes of *W. euthysepta* came from the Stonefort limestone member of the Tradewater formation of southern Illinois. Galloway and Ryniker referred to this species specimens from the upper portion of the Atoka formation of Latimer County, Oklahoma; White referred to it specimens from the Millsap formation of Texas. Also, Roth has referred with question to this species specimens from the Minnelusa formation of South Dakota (Black Hills) and beds of Cherokee age of Colorado, and I have referred specimens from the Cherokee of Iowa to it with question.

Hypotypes, Univ. of Iowa, 1016–1019.

Genus FUSULINA Fischer de Waldheim

FUSULINA LEEI Skinner

Plate 26, figures 17–19

Fusulina leei SKINNER, *1931*, Jour. Paleontology, vol. 5, pp. 257–258, pl. 30, figs. 4, 6.—THOMPSON, *1934*, Univ. Iowa Studies Nat. Hist., vol. 16, pp. 301–303, pl. 21, figs. 3, 7, 10, 18.

Among the collections from Oklahoma that I am studying there is a small group of rather poorly preserved specimens from the upper portion of the Boggy formation of Pontotoc County which are clearly conspecific with the holotype of *Fusulina leei* Skinner, which came from immediately over the Bluejacket sandstone (Cherokee) of Mayes County, Oklahoma, and with the specimens from the Des Moines series of Iowa that I recently referred to this species. However, this species has been adequately described and there is no need to duplicate that work.

The only sections obtained suitable for detailed study are of specimens of only four to five volutions or less. These specimens measure about 2.55 mm. in length and 0.85 mm. in width. The form ratio is 1:3.0. The inside diameter of the proloculum measures about 75 microns. The tunnel angle measures 35 to 43 degrees in the fourth volution. The septal count gives 13 for the second volution, 15 for the third volution and 18 for the fourth volution.

Occurrence.—The specimens from Pontotoc County, Oklahoma, came from the upper portion of the Boggy formation above and below a 4-inch limestone in the south bank of Bois d'Arc Creek, in the center of the SW.¼ NE.¼ sec. 17, T. 2 N., R. 7 E. (Pl. 26, figs. 17–19). The types of this species were described from immediately over the Bluejacket sandstone of Mayes County, Oklahoma, and I have described specimens from approximately 35 feet below the White Breast coal of the Cherokee of Iowa.

Hypotypes, Univ. Iowa, 1020–1022, 1024–1025.

FUSULINA spp.

The collections I am studying contain a few representatives of two species which are clearly referable to *Fusulina* s. s., but unfortunately neither of them is well enough represented to enable me to determine its specific characters with certainty.

The lowest horizon from which I have specimens of this genus is a brownish-gray shale in the center of the SW.¼ NW.¼ NW.¼ sec. 27, T. 3 N., R. 7 E., Pontotoc County, Oklahoma. Morgan (11, p. 244) considered this shale to be lower Boggy in age. Only a very few specimens were obtained from this locality. They are rather long and slender and have very weakly fluted septa. The small amount of data that can be gleaned from these specimens suggest that they are rather closely related to the small form from the Hartville limestone of Wyoming that Roth and Skinner described in 1930 as *Fusulina hartvillensis*.

Another group of specimens of this genus, which are very poorly preserved, were obtained from the "overlapping Boggy"[4] in the center of the line between secs. 25 and 26, T. 3 N., R. 7 E., Pontotoc County, Oklahoma. These specimens are too poorly preserved to permit satisfac-

[4] Described by Morgan (11, pp. 19, 44, 48) as an unconformable overlap.

tory specific comparisons, but in general shape they resemble *Fusulina pumila* Thompson of the Cherokee of Iowa.

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CONODONTS FROM THE UPPER AND MIDDLE ARKANSAS NOVACULITE, MISSISSIPPIAN, AT CADDO GAP, ARKANSAS

CHALMER L. COOPER
Walker Museum, University of Chicago, Chicago, Illinois

ABSTRACT

The novaculite at Caddo Gap is about 900 feet thick and is typical of the formation in the Ouachita Mountains. It is divisible into three units—a lower division consisting of massive thick-bedded novaculite; a middle division of dark-colored dense novaculite and shale; and an upper division made up mostly of massive calcareous novaculite. A faunal chart shows that the conodont fauna of the Arkansas novaculite, the Woodford formation of Oklahoma, the Hardin sandstone of Tennessee, and the Chattanooga shale of Alabama, as well as smaller collections of conodonts from the Ohio and Sunbury shales, are remarkably similar. Of the 45 species found in the novaculite, 27 are found in the Woodford, 14 in the Hardin and 17 in the Chattanooga. Eight of the species are new. The evidence furnished by the conodonts indicates that the upper and middle divisions of the Arkansas novaculite are Mississippian.

This paper is the third in a series presenting the results of the writer's study of the conodont fauna of the Early Mississippian black shales of the Central States. The previous papers deal with the conodont fauna of the Woodford formation and Arkansas novaculite of Oklahoma, the Ohio and Sunbury shales of Ohio (1)[1] and with the new species found in the Woodford formation (2).

One of the best, as well as thickest, exposures of the Arkansas novaculite in the Ouachita Mountains is found at Caddo Gap in west-central Arkansas, in secs. 18 and 19, T. 4 S., R. 24. W., Montgomery County. The Gap is formed by the Caddo River which cuts across the south slope of the Caddo Mountains, a steep ridge formed by the very resistant novaculite beds. Miser (5) measured the formation along the river and railroad cut many years ago. Since then a state highway has been constructed on the east side of the railroad. In building the road two deep cuts were made which provide an excellent and complete exposure of the steeply dipping beds of the novaculite.

In March, 1930, a collection of conodonts was made from the middle division of the novaculite. The amount of material obtained was small because the exposure was not reached until late in the day, but more time was available on a second visit made in the company of Mr. Miser, who relocated the beds in which he had previously collected conodonts. With his aid, an extensive collection was made from seven horizons in the upper and middle divisions of the formation.

The novaculite at this locality is typical of the formation as exposed over most of the Ouachita Mountain region. It is divisible into three

[1] Numbers refer to bibliography at end of paper.

lithological units—a lower division consisting almost entirely of massive and thick-bedded white novaculite; a middle division of interbedded dark-colored dense novaculite and shale; and an upper division made up mostly of massive calcareous novaculite. The strike of the formation is east-west and the dip is about 80° S. The total thickness of the Caddo Gap section as measured by Miser is 891 feet 5 inches, divided as follows: lower division, 410 feet; middle, 363 feet 7 inches; and upper, 117 feet 10 inches. This section is reproduced in detail so that the conodont-bearing horizons may be readily located. The numbers have been added by the writer to facilitate reference to the members.

Section of the Arkansas novaculite on east side of Caddo River at Caddo Gap
(5, pp. 44–45)

	Ft.	in.
STANLEY SHALE		
ARKANSAS NOVACULITE		
Upper division—		
18. Dark-colored dense novaculite in two layers	1	10
17. Concealed	1	
16. Massive white novaculite in beds ranging in thickness from a few inches to 3 feet. Much of it is dense and hard, though most of it is porous and soft, crumbling into white powder when struck with a hammer. Slickensides were observed near the middle of the bed	115	
Middle division—		
15. Buff to red, though at the top somewhat greenish shale containing minute yellow specks and many thin layers of dense light-colored novaculite, which is in part laminated	11	
14. Thin-bedded, dense, black novaculite. Interbedded shale is in subordinate amount at the base, but nearer the top it predominates	14	
13. Layer of black dense novaculite, the lower half of which is a minutely pebbled conglomerate and contains numerous conodonts	6	
12. Black, dense, thin-bedded, laminated novaculite with subordinate amount of drab, interbedded shale	21	
11. Black, minutely pebbled novaculite conglomerate containing numerous conodonts	1	
10. Black, dense novaculite and dark-colored shale	2	
9. Concealed	65	
8. Black and greenish-gray clay shale with a few thin layers of dense novaculite. Conodonts, linguoids, and *Sporangites* were collected from thin layers in this bed	19	
7. Dense black novaculite in thin layers, some 1 foot thick. Some of the layers have poor cleavage and others are finely laminated with parallel black and white bands; a few containing sand. Black shale in thin layers alternating with those of the novaculite makes up half or nearly half of this bed. The strata are intensely jointed and are somewhat contorted, so the actual thickness would be less than here indicated	230	
6. Concealed	1	
Lower division—		
5. Much jointed, white, dense novaculite. Bedding can not be detected because of joints. An exposure of 40 to 50 feet at one place is apparently an exposure of a single massive bed. Slickensides are common in places. At the top, which is toward the south, the novaculite is brecciated, the fragments being cemented together and partly replaced by limonite. A coating of manganese dioxide is common along the joints	115	
4. White dense novaculite in massive beds, some about 10 feet thick. In places thin lenses wedge in between the thicker beds. The whole is much jointed. Small oval cavities and fine laminations are present in some layers.		

	At the top there are thin coatings of manganese dioxide along the joints. Some of these coatings are small concentric rings.....	215
3.	Yellow hard shale interbedded with probably an equal amount of dense, white to yellow novaculite in thin layers.....	29
2.	Dense white novaculite, most of whose beds are less less than a foot thick. The top is 3 feet thick and in its upper 2 or 3 inches are subangular to angular pebbles or fragments of novaculite.	35
1.	Black and buff shale interbedded with thin layers of dense novaculite.....	16
		891 5

MISSOURI MOUNTAIN SLATE: Red and buff slate.

The chart on page 310 shows the remarkable similarity of the fauna of the several formations considered. This is particularly true when the fauna of the various members of the upper[2] and middle Arkansas novaculite is compared with that of the Woodford formation of Oklahoma, the Hardin sandstone of Tennessee, and the Chattanooga shale of Alabama. To a lesser extent the fauna of the Ohio and Sunbury shales of Ohio are also similar. The last two faunas, though represented by small collections, include a number of species found in the Arkansas novaculite. Of the 45 species found in the novaculite, 27 are found in the Woodford, 14 in the Hardin sandstone, and 17 in the Chattanooga shale. The three most characteristic forms are *Hindeodella subtilis*, *Polygnathus pennatulus*, and *Synprioniodina alternata*. The first is found in all collections, the second in all but two, and the third in 11 of the 14 collections. Eight new species are described, and a few forms which are found in the Woodford as well as in the novaculite are also illustrated.

Ulrich (5, p. 58) has stated that "the middle and perhaps also the upper division are to be correlated with the Woodford chert in the Arbuckle Mountains and with the Chattanooga shale. . . . a small part of the middle division is of the same age as the Genessee shale of the Appalachian region." The evidence for the statement is thought to be based on a linguoid fauna, collected from bed 8 at Caddo Gap.[3] In view of the evidence furnished by the

[2] An early draft of this paper was submitted to Mr. Miser for criticism. In reply Mr. Miser thought that possibly two collections labeled as horizons in bed 16, the lower member of the upper division, actually came from the middle division, since he had never found the beds of the upper division of the novaculite to be fossiliferous. The collections in question were sent to Mr. Miser, who could not definitely recognize the horizon from the character of the rock containing the conodonts. Opportunity for another visit to the locality was afforded the writer in March, 1932, and at that time it was determined that the fossils were collected from two horizons, separated by only a few feet of strata, in an area of outcrop a few rods south of the main outcrop. The second exposure is due to repetition by faulting. The place of collecting was about the middle of the exposure, and since the upper contact was obscured by Stanley shale float and the lower contact faulted out, absolute determination of the exact horizon with reference to the contact with the upper and middle divisions was not possible. The lithologic character of the beds fits Mr. Miser's description of bed 16 and does not correspond to any of the beds of the middle division. For the reasons set forth above the collections made from the two horizons have been listed as beds *A* and *B* in the faunal chart and are at least provisionally regarded as two horizons in bed 16, the lower member of the upper division.

[3] Miser, Hugh D., Personal communication.

Faunal Chart	Figure Number	Arkansas Novaculite Caddo Gap, Arkansas							Woodford, Ada, Okla.[a]	Woodford, Ti, Okla.[b]	Arkansas novaculite, Okla.[c]	Ohio shale, Ohio[d]	Sunbury shale, Ohio[e]	Chattanooga shale, Ala.[f]	Hardin sandstone, Tenn.[g]
		Bed Number													
		7	8	13	14	15	A*	B							
Prioniodus alabamensis Holmes	1					×								×	
Prioniodus alatoides Holmes	2		×			×	×		×					×	
Prioniodus alatoideus Cooper	3				×		×		×						
Prioniodus culturatus Ulrich and Bassler	4		×?	×			×		×					×	×
Prioniodus curvatus Cooper	5						×								
Prioniodus obtusidens Cooper	6			×											
Prioniodus parvus Cooper	7			×											
Ligonodina gouldi Cooper	8			×			×								
Ligonodina curvata Cooper	9						×								
Prioniodella gracilus Ulrich and Bassler	10				×										×
Prioniodella aciedentata Cooper	11						×		×						
Bryantodus angulatus Cooper	12		×						×						
Bryantodus germanus Holmes	13		×	×					×	×		×		×	
Bryantodus gracilus Ulrich and Bassler	14	×	×				×	×							×
Bryantodus inclinatus Holmes	15	×		×				×	×					×	
Bryantodus inequialis Holmes	16	×	×	×	×			×	×		×	×	×	×	
Bryantodus subradiatus Ulrich and Bassler	18	×		×		×	×		×						×
Eupriniodina macrodentata Cooper	20						×		×						
Lonchodina discreta Ulrich and Bassler	21					×			×					×	×
Lonchodina irregularis Holmes	22		×?								×			×	
Hindeodella curvidens Cooper	23	×			×				×						
Hindeodella crassidens Cooper	24	×	×						×						
Hindeodella germana Holmes	25		×			×			×					×	
Hindeodella pumilla Cooper	26		×						×						
Hindeodella subtilis Ulrich and Bassler	27	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Hindeodella subtilita Cooper	28					×			×						
Hindeodella petila Cooper	29			×					×						
Hamulosodina nodosa Cooper	30	×			×				×						
Hamulosodina simplex Cooper	31						×		×						
Diplododella bilateralis Ulrich and Bassler	32		×				×							×	×
Palmatodella delicatula Ulrich and Bassler	33		×						×					×	×
Palmatodella inflexa Cooper	34				×				×						
Synprioniodina alternata Ulrich and Bassler	35	×	×	×	×	×	×		×			×	×	×	×
Polygnathus crassus Cooper	36		×		×	×			×						
Polygnathus delicatulus Ulrich and Bassler	37				×										×
Polygnathus pennatulus Ulrich and Bassler	38	×		×		×	×	×	×	×	×	×	×	×	×
Polygnathellus carinatus Cooper	17				×										
Polygnathellus parilis Cooper	19							×							
Ancyrodella hamata Ulrich and Bassler	39	×		×				×							
Palmatolepis elongata Holmes	40		×	×	×									×	×
Palmatolepis lobatula Ulrich and Bassler	41					×									×
Palmatolepis perlobatus Ulrich and Bassler	42		×		×	×			×					×	×
Palmatolepis regularis Cooper	43		×	×					×						
Palmatolepis ovatus Cooper	44					×	×								
Spathodus subrectus (Holmes)	45			×										×	

* See footnote, page 309.

[a] Lower part of Woodford shale, sec. 3, T. 2 N., R. 6 E., Oklahoma.
[b] Woodford shale, Ti Valley, southern Pittsburg County, Oklahoma.
[c] Lower-middle Arkansas novaculite, sec. 8, T. 2 N., R. 21 E., Oklahoma.
[d] Top of Ohio shale, northeast of Columbus, Ohio.
[e] Sunbury shale, near base, northeast of Columbus, Ohio.
[f] Chattanooga shale, Huntsville, Alabama. (See No. 4 of Bibliography.)
[g] Hardin sandstone, Mt. Pleasant, Tennessee. (See No. 7 of Bibliography.)

fauna collected in bed 7 (lower-middle division) and that found at the very base of the middle division in Oklahoma, (1, pp. 144–145) the writer is inclined to place the entire middle division in the Mississippian. Ulrich (6) stated in 1911 that the Arkansas novaculite "cannot be younger than Waverlian and is probably much older—that is Oriskanian." He now holds that only the lower division is of Onondaga (Middle Devonian) age, based on a collection of fossils from novaculite beds near Ti, Oklahoma. These beds underlie a bed of chert which has the same stratigraphic position as the Woodford and which also has the same lithologic character. The correlation of this bed overlying the novaculite with the Woodford was later established more conclusively, (1, p. 151, faunal chart). From the evidence now at hand it appears that the whole of the Arkansas novaculite is not a unit, but that the upper and middle divisions are of Early Mississippian (early Kinderhook) age, whereas the lower division is of Middle Devonian age.

Since the formation as now defined does not conform with the best practices of geologic nomenclature, it should be redefined and raised to group rank. Two new names, one for the predominantly novaculitic lower division and a second for the upper and middle divisions, should be chosen. In deference to Mr. Miser's suggestion that the formation not be renamed until the new contact can be mapped in the field, the matter is left open at this time. It is suggested, however, that when the formation is redefined, that the name Caddo Gap be used for the Mississippian portion, because of the complete and well exposed outcrops at that locality.

DESCRIPTION OF SPECIES

The entire fauna of the upper and middle divisions will not be described, but the faunal chart on page 310 and the plate will show the complete list. Only the new species and those which have not been described before from the Woodford formation or the novaculite will be described in the following pages. The fauna totals 45 species, representing 16 genera. Of these 17 are described in this paper.

Family PRIONIODIDAE Ulrich and Bassler, 1926

Genus PRINIODUS Pander, 1856

PRIONIODUS ALABAMENSIS Holmes, 1928
Plate 27, figure 1

Prioniodus alabamensis HOLMES, *1928*, U. S. Nat. Mus., Proc., vol. 72, art. 5, p. 24, pl. 9, figs. 1, 2.

Bar straight, with very long, thin, tapering cusp that is recurved toward the posterior end. The bar carries straight tapering denticles inclined slightly toward the posterior end. Holmes' description states that the cusp is not produced below the bar, but her figure 1 shows this projection, much like the specimen figured here.

Arkansas novaculite, bed 15, Caddo Gap, Ark.

PRIONIODUS CURVATUS Cooper, n. sp.
Plate 27, figure 5

The bar is straight and rather slender, carrying numerous thin tapering denticles of more or less uniform size. The cusp is slender, tapering gradually to a point, and is straight beyond the decided curvature near the lower third of its

length. The projection tapers rapidly to a point and is about one-half the length of the cusp. *Prioniodus curvatus* differs from *P. spicatulus* Ulrich and Bassler in

EXPLANATION OF PLATE 27

FIG. 1—*Prioniodus alabamensis* Holmes, ×15. Walker Mus. (Univ. Chicago), 38051. (p. 311)
2—*Prioniodus alatoides* Holmes, ×22. Walker Mus. (Univ. Chicago), 38052.
3—*Prioniodus alatoideus* Cooper, ×30. Walker Mus. (Univ. Chicago), 38053.
4—*Prioniodus culturatus* Ulrich and Bassler, ×22. Walker Mus. (Univ. Chicago), 38054.
5—*Prioniodus curvatus* Cooper, n. sp., ×24. Walker Mus. (Univ. Chicago), 38055. (p. 311)
6—*Prioniodus obtusidens* Cooper, n. sp., ×24. Walker Mus. (Univ. Chicago), 38056. (p. 313)
7—*Prioniodus parvus* Cooper, n. sp., ×24. Walker Mus. (Univ. Chicago), 38057. (p. 313)
8—*Ligonodina gouldi* Cooper, n. sp., ×15. Walker Mus. (Univ. Chicago), 38058. (p. 313)
9—*Ligonodina curvata* Cooper, n. sp., ×24. Walker Mus. (Univ. Chicago), 38059. (p. 313)
10—*Prioniodella gracilis* Ulrich and Bassler, ×15. Walker Mus. (Univ. Chicago), 38060. (p. 313)
11—*Prioniodella aciedentata* Cooper, ×22. Walker Mus. (Univ. Chicago), 38061.
12—*Bryantodus angulatus* Cooper, ×40. Walker Mus. (Univ. Chicago), 38062.
13—*Bryantodus germanus* Holmes, ×30. Walker Mus. (Univ. Chicago), 38063.
14—*Bryantodus gracilis* Ulrich and Bassler, ×15. Walker Mus. (Univ. Chicago), 38064.
15—*Bryantodus inclinatus* Holmes, ×30. Walker Mus. (Univ. Chicago), 38065.
16—*Bryantodus inequialis* Holmes, ×22. Walker Mus. (Univ. Chicago), 38066.
17—*Polygnathellus carinatus* Cooper, n. sp., ×24. Walker Mus. (Univ. Chicago), 38067. (p. 315)
18—*Bryantodus subradiatus* Ulrich and Bassler, ×22. Walker Mus. (Univ. Chicago), 38068.
19—*Polygnathellus parilis* Copper, n. sp., ×24. Walker Mus. (Univ. Chicago), 38069. (p. 315)
20—*Euprioniodina macrodentata* Cooper, ×22. Walker Mus. (Univ. Chicago), 38070.
21—*Lonchodina discreta* Ulrich and Bassler, ×30. Walker Mus. (Univ. Chicago), 38071.
22—*Lonchodina irregularis* Holmes, ×15. Walker Mus. (Univ. Chicago), 38072. (p. 314)
23—*Hindeodella curvidens* Cooper, ×22. Walker Mus. (Univ. Chicago), 38073.
24—*Hindeodella crassidens* Cooper, ×22. Walker Mus. (Univ. Chicago), 38074.
25—*Hindeodella germana* Holmes, ×22. Walker Mus. (Univ. Chicago), 38075.
26—*Hindeodella pumilla* Cooper, ×22. Walker Mus. (Univ. Chicago), 38076.
27—*Hindeodella subtilis* Ulrich and Bassler, ×22. Walker Mus. (Univ. Chicago), 38077.
28—*Hindeodella subtilita* Cooper, ×22. Walker Mus. (Univ. Chicago), 38078.
29—*Hindeodella petila* Cooper, ×30. Walker Mus. (Univ. Chicago), 38079.
30—*Hamulosodina nodosa* Cooper, ×30. Walker Mus. (Univ. Chicago), 38080.
31—*Hamulosodina simplex* Cooper, ×22. Walker Mus. (Univ. Chicago), 38081.
32—*Diplododella bilateralis* Ulrich and Bassler, ×15. Walker Mus. (Univ. Chicago), 38082. (p. 314)
33—*Palmatodella delicatula* Ulrich and Bassler, ×22. Walker Mus. (Univ. Chicago), 38083.
34—*Palmatodella inflexa* Cooper, ×22. Walker Mus. (Univ. Chicago), 38084.
35—*Synprioniodina alternata* Ulrich and Bassler, ×30. Walker Mus. (Univ. Chicago), 38085.
36—*Polygnathus crassus* Cooper, ×22. Walker Mus. (Univ. Chicago), 38086.
37—*Polygnathus delicatulus* Ulrich and Bassler, ×15. Walker Mus. (Univ. Chicago), 38087. (p. 314)
38—*Polygnathus pennatulus* Ulrich and Bassler, ×22. Walker Mus. (Univ. Chicago), 38088.
39—*Ancyrodella hamata* Ulrich and Bassler, ×15. Walker Mus. (Univ. Chicago), 38089.
40—*Palmatolepis elongata* Holmes, ×20. Walker Mus. (Univ. Chicago), 38090. (p. 314)
41—*Palmatolepis lobatula* Ulrich and Bassler, ×15. Walker Mus. (Univ. Chicago), 38091. (p. 314)
42—*Palmatolepis perlobatus* Ulrich and Bassler, ×22. Walker Mus. (Univ. Chicago), 38092.
43—*Palmatolepis regularis* Cooper, ×22. Walker Mus. (Univ. Chicago), 38093.
44—*Palmatolepis ovatus* Cooper, n. sp., ×24. Walker Mus. (Univ. Chicago), 38094. (p. 314)
45—*Spathodus subrectus* (Holmes) ×15. Walker Mus. (Univ. Chicago), 38095. (p. 315)

Cooper, Mississippian Conodonts

the greater development of the downward projection of the main cusp. The cusp is also more strongly curved.

Arkansas novaculite, bed A, Caddo Gap, Ark.

PRIONIODUS OBTUSIDENS Cooper, n. sp.
Plate 27, figure 6

The bar is straight and fairly broad, carrying ten blunt denticles of irregular length. All denticles stand upright from the bar, except the final one which is inclined toward the posterior end. The cusp is broken, so that its attitude and length are unknown. The projection is short, narrow and pointed. This species differs from *P. alatus* Hinde in the character of the anterior end.

Arkansas novaculite, bed 13, Caddo Gap, Ark.

PRIONIODUS PARVUS Cooper, n. sp.
Plate 27, figure 7

A small form, differing greatly from other described species in the strongly curved bar and a small number of denticles. The denticles, four in number, are fairly broad and slightly tapering and strongly inclined toward the posterior end, which is terminated by a fifth short, pointed denticle. The cusp is broken, the fragment indicating that it stood at right angles to the bar. The projection is broad and distinctly curved backward, ending in a sharp point.

Arkansas novaculite, bed 13, Caddo Gap, Ark.

Family PRIONIODINIDAE Ulrich and Bassler, 1926

Genus LIGONODINA Ulrich and Bassler, 1926

LIGONODINA GOULDI Cooper, n. sp.
Plate 27, figure 8

The bar is straight or very slightly curved with long tapering denticles alternating with slender shorter ones. The cusp is long and broad at the base, and gradually tapering to a point. The cusp and denticles are slightly inclined to the bar. The projection is rather broad, about one-half the length of the cusp, and carries bases of five denticles[4] along its front margin. This species differs from *Ligonodina deflecta* Ulrich and Bassler in its straighter bar and its longer, more slender denticles.

Arkansas novaculite, beds 13 and A, Caddo Gap, Ark.

LIGONODINA CURVATA Cooper, n. sp.
Plate 27, figure 9

The bar is straight and broad with seven slightly inclined denticles, the last one forming the end of the bar and more inclined than the rest. The cusp is relatively short and narrow, and recurved. The projection is almost as long as the cusp, broader, and with the bases of the denticles so inclined that they have somewhat the appearance of being developed on the anterior side.

Arkansas novaculite, bed A, Caddo Gap, Ark.

Genus PRIONIODELLA Ulrich and Bassler, 1926

PRIONIODELLA GRACILIS Ulrich and Bassler, 1926
Plate 27, figure 10

Prioniodella gracilis ULRICH and BASSLER, *1926*, U. S. Nat. Mus., Proc., vol. 68, art. 12, p. 20, pl. 10, figs. 22, 23.

The bar is straight except for the anterior end, which is curved to make a slight downward projection. The denticles are slender, tapering, and slightly inclined backward.

Arkansas novaculite, bed 14, Caddo Gap, Ark.

[4] The writer pointed out in 1933 (3), that *Ligonodina* does not possess the "suckerlike impressions" ascribed to it in Ulrich and Bassler's description, but that it possesses instead, denticles on the downward projection. The "impressions" previously noted and described are the bases of the denticles which have been broken from the projection. It was also pointed out that described species of *Prioniodus* Pander possess denticles on the under side of the projection, which necessitates the reclassification of all such species and their transfer to the genus *Ligonodina*.

Genus BRYANTODUS Ulrich and Bassler, 1926

BRYANTODUS GRACILIS Ulrich and Bassler, 1926

Plate 27, figure 14

Bryantodus gracilis ULRICH and BASSLER, *1926*, U. S. Nat. Mus., Proc., vol. 68, art, 12, p. 27, pl. 10, fig. 10.

The bar is slender and the denticles are short and slender. The main cusp is broader and about three times as long as the denticles. The entire tooth is strongly arched.

Arkansas novaculite, beds 7, 8, A and B, Caddo Gap, Ark.

Genus LONCHODINA Ulrich and Bassler, 1926

LONCHODINA IRREGULARIS Holmes, 1928

Plate 27, figure 22

Lonchodina irregularis HOLMES, *1928*, U. S. Nat. Mus., Proc., vol. 72, art. 5, p. 26, pl. 9, fig. 12.

This species is similar to the species listed by Holmes. The bar is strongly arched, more strongly so on the anterior end. The denticles are alternately large and small, but become shorter posteriorly.

Arkansas novaculite, bed 8?, Caddo Gap, Ark.

Genus DIPLODODELLA Ulrich and Bassler, 1926

DIPLODODELLA BILATERALIS Ulrich and Bassler, 1926

Plate 27, figure 32

Diplododella bilateralis ULRICH and BASSLER, *1926*, U. S. Nat. Mus., Proc., vol. 68, art. 12, p. 41, text fig. 21, p. 16.

The specimen is identical with those figured by Ulrich and Bassler and Holmes from the Chattanooga shale. The bar is strongly arched and of about equal length on each side of the main cusp. The denticles are closely spaced, slender, and the main cusp is much longer and broader than the denticles.

Arkansas novaculite, beds 8 and A, Caddo Gap, Ark.

Family POLYGNATHIDAE Ulrich and Bassler, 1926

Genus POLYGNATHUS (Hinde) Bryant, 1921

POLYGNATHUS DELICATULUS Ulrich and Bassler, 1926

Plate 27, figure 37

Polygnathus delicatulus ULRICH and BASSLER, *1926*, U. S. Nat. Mus., Proc., vol. 68, art. 12, p. 45, pl. 7, figs. 9, 10.

The outline is lanceolate with a long and slender "stem." The surface markings are delicate and arranged transversely.

Arkansas novaculite, bed 14, Caddo Gap, Ark.

Genus PALMATOLEPIS Ulrich and Bassler, 1926

PALMATOLEPIS ELONGATA Holmes, 1928

Plate 27, figure 40

Palmatolepis elongata HOLMES, *1928*, U. S. Nat. Mus., Proc., vol. 72, art. 5, p. 33, pl. 11, fig. 13.

The plate is long and narrow with a finely denticulated ridge extending its entire length, though low and indistinct near the center. The surface is rather smooth and free of ornamentation other than the median ridge.

Arkansas novaculite, beds 8, 13, and 14, Caddo Gap, Ark.

PALMATOLEPIS LOBATULA Ulrich and Bassler, 1926

Plate 27, figure 41

Palmatolepis lobatula ULRICH and BASSLER, *1926*, U. S. Nat. Mus., Proc., vol. 68, art. 12, p. 50, pl. 7, figs. 3, 4.

The plate is lobate in outline, with bifurcation anteriorly. The surface is without ornamentation except the ridge running the whole length of the shell.

Arkansas novaculite, bed 15, Caddo Gap, Ark.

PALMATOLEPIS OVATUS Cooper, n. sp.

Plate 27, figure 44

The outline is ovate, almost circular. The median ridge broadens near the

center of the plate, and the surface is without other ornamentation, or is sometimes covered with fine tuberculation without definite arrangement.

Arkansas novaculite, beds 15 and A, Caddo Gap, Ark.

Genus SPATHODUS
Branson and Mehl, 1933

SPATHODUS SUBRECTUS (Holmes), 1928
Plate 27, figure 45

Panderodella subrecta HOLMES, *1928*, U. S. Nat. Mus., Proc., vol. 72, art. 5, p. 31, pl. 10, fig. 15. COOPER, *1931*, Jour. Paleontology, vol. 5, p. 151, pl. 20, fig. 18.

Spathodus subrectus (Holmes) HUDDLE, *1934*, Bull. Am. Paleontology, vol. 21, p. 277, pl. 7, fig. 17.

The bar is rather straight and short. The denticles are closely arranged, about equal in size, blunt, and apparently fused in the lower half.

Arkansas novaculite, bed 13, Caddo Gap, Ark.

Genus POLYGNATHELLUS
Ulrich and Bassler, 1926

POLYGNATHELLUS CARINATUS Cooper, n. sp.
Plate 27, figure 17

The tooth is curved with the main cusp and broad and short. The denticles are closely spaced, with about twice as many on one side as the other. The "keel" or basal expansion is prominent the entire length of the bar.

Arkansas novaculite, bed 14, Caddo Gap, Ark.

POLYGNATHELLUS PARILIS Cooper, n. sp.
Plate 27, figure 19

The tooth differs from *P. carinatus* in its more equally proportioned bar, the main cusp being almost in the center of the bar, with five denticles on one side and six on the other. The denticles are broad, close set, and rather blunt. The cusp is less than twice as long as the denticles and the bar is arched.

Arkansas novaculite, bed B, Caddo Gap, Ark.

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OSTRACODA FROM THE BASAL MISSISSIPPIAN SANDSTONE IN CENTRAL MISSOURI

PHILIP S. MOREY
University of Missouri, Columbia, Missouri

ABSTRACT

Few species of ostracodes are known from Kinderhook, Early Mississippian, rocks. This paper describes an ostracode fauna collected from the thin basal Mississippian sandstone which occurs in central Missouri. This sandstone, previously called Sylamore, is believed to represent the Bushberg sandstone instead. Fourteen ostracode genera are recognized, including two new genera, *Plagionephrodes* and *Hypotetragona*. Twenty-four species are described, all but one of which are new.

The basal Mississipppian in central Missouri is a sandstone which was long considered as the equivalent of the Sylamore sandstone of Stone County, Arkansas (1, 2, 3, 5).[1] Investigation by Branson and Mehl of the conodont fauna of the Sylamore of Stone County has shown that it is Devonian in age and the equivalent of the Grassy Creek formation of Missouri (4). The sandstone in central Missouri unquestionably is of Early Mississippian age. It is considered to be Bushberg in age by Branson and Mehl. A report on the stratigraphy of this sandstone in Missouri has been completed by Professor Branson and the writer has had the opportunity of reading the manuscript and has taken the following brief description from it.

In central Missouri the sandstone is typically bluish-green in color but in a few places it is white or brown. In the main it is poorly consolidated and friable, but in some places it is quartzitic and shows secondary growth of quartz grains. Some parts of the sandstone are shaly and others are conglomeratic, but the predominant material is quartz sand. The usual thickness of the formation is between a few inches and 2 or 3 feet, but in places, in old stream valleys, it may be as much as 60 feet thick.

The sandstone in central Missouri may be recognized by its blue-green color, and by the presence of the teeth of *Ptyctodus calceolus* and of small black nodules. Where these are absent it is possible to identify the sandstone only by its stratigraphic position.

Most of the Ostracoda described in this paper were collected from a locality about 3 miles north of the town of Williamsburg, in sec. 9, T. 48 N., R. 7 W., Callaway County. At this place the sandstone outcrops for about 20 feet in the bottom of a side valley of Clark's Branch, a tributary of Whetstone Creek. It is about 6 inches thick and is composed of bluish-green friable sandstone

[1] Numbers refer to bibliography at end of the paper.

containing silicified microfossils and fish teeth. It apparently overlies the Snyder Creek formation of Upper Devonian age, and is overlain by the Chouteau limestone of Early Mississippian age.

Few of the Ostracoda from this locality are well preserved. They are composed of an inner layer or filling of clear crystalline silica and a thin outer layer of amorphous or finely crystalline flaky silica which is brittle and comes off easily from the inner layer. The outer layer is apparently the replacement of the original carapace and the inner clear material is a cast. Good casts are numerous but the few specimens having the replaced carapace still intact are usually rough and irregular on the surface. Impressions made by sand grains, probably at the time of replacement, are numerous.

Material containing a few Ostracoda was collected from exposures of the sandstone at the stations of Easley and Providence along the M. K. and T. tracks bordering the Missouri River, and at several places between the two stations. Some specimens were found in the sandstone near the mouth of the north fork of Rocky Fork Creek, 3 miles north of Brown's, in sec. 31, T. 47 N., R. 31 W. These stations are all in Boone County. Samples from sec. 12, T. 48 N., R. 6 W., a quarry near the bridge across Clear Fork Creek, about 2 miles north of Danville, Montgomery County, yielded a few poor specimens.

Few Ostracoda have been described from the Kinderhookian formations of North America, and, as none described is similar to any of the species from the sandstone, no comparisons of correlative value can be made.

The writer is indebted to Prof. E. B. Branson for advice in preparation of the manuscript and for aid in field work and collecting; and to Dr. H. N. Coryell for reading the paper and for many pertinent suggestions.

SYSTEMATIC DESCRIPTIONS

Family LEPERDITELLIDAE Ulrich and Bassler, 1906

Genus PARAPARCHITES Ulrich and Bassler, 1906

PARAPARCHITES NICKLESI (Ulrich), 1891

Plate 28, figure 26

Leperditia nicklesi ULRICH, *1891*, Cincinnati Soc. Nat. Hist., Jour., vol. 13, p. 200, pl. 18, figs. 1 *a–e*.

Paraparchites nicklesi GIRTY, *1911*, U. S. Geol. Survey, Bull. 439, p. 105, pl. 9, figs. 2–5.—Harlton, *1929*, Am. Jour. Sci., vol. 18, p. 255, pl. 1, fig. 1.

Two specimens of *P. nicklesi* that did not possess tubercles were found near Williamsburg. A single specimen with a fairly prominent tubercle on the left valve was found at the same locality.

Length, 1.0 mm.; height, 0.8 mm.; thickness, 0.45 mm.

Figured specimen, Univ. Missouri, 0.1000–2.

Basal Mississippian sandstone, 3 miles north of Williamsburg, Missouri. Also found in the Warsaw, Glen Dean, Moorfield, Batesville, and Fayetteville formations of the Mississippian of the central United States.

PARAPARCHITES DISJUNCTUS Morey, n. sp.

Plate 28, figures 9, 13

Carapace small, middle third of carapace strongly tumid; dorsal margin

gently convex; posterior end much larger and more broadly rounded than narrow anterior end; maximum height in posterior half; greatest convexity of left valve in posterior half at mid-line, greatest convexity of right valve in posterior half below median line; dorsal margin of right valve straight; left valve strongly peripheral to right dorsally; dorsal surface of carapace flattened, sloping from highest part of left valve almost to mid-line of right valve, with hinge in plane of flattened portion; right valve peripheral to and overlapping left on free edges, most strongly on ventral edge; surface of carapace smooth.

The flattened sloping dorsal surface and the difference in the positions of greatest convexity of the two valves give the carapace a distorted appearance in end view. From this appearance the specific name is derived.

Length, 0.7 mm.; height, 0.4 mm.

Syntypes, Univ. of Missouri, 0.1000–3.

Common in the basal Mississippian sandstone, 3 miles north of Williamsburg, Missouri.

Family KLOEDENELLIDAE Ulrich and Bassler, 1923

Genus DIZYGOPLEURA Ulrich and Bassler, 1923

DIZYGOPLEURA MEHLI Morey, n. sp.

Plate 28, figure 19

Carapace subrhomboidal in lateral outline; hinge impressed, edges of valves on either side of hinge flat, sloping in toward hinge; dorsal surfaces of valves smooth and flattened; hinge essentially straight, tooth and socket large and strong; carapace distinctly quadrilobate; dorsal margin slightly convex, greatest convexity in posterior half; posterior dorsal angle acute; anterior dorsal angle low, broadly obtuse; anterior margin typically evenly rounded; in some specimens the dorsal half of anterior margin may be almost straight; posterior margin gently convex, flattened, appearing truncate compared to anterior margin; ventral margin slightly concave over most of its length; maximum height at position of tooth and socket; outline of carapace in dorsal view bluntly wedge-shaped, thickest through posterior lobe; posterior sulcus long, curving anteriorly near ventral margin, anterior sulcus equal in length to posterior, curving posteriorly near ventral margin, and the sulci, almost meeting at middle of valve, united by a shallow sinus; anterior sulcus broad and deep, bottom rounded, walls flat, anterior wall almost at right angles to plane of valves, posterior wall more gently inclined; posterior sulcus deep and narrow, bottom rounded, anterior wall flat and at right angles to plane of valves, posterior wall convex and inclined; median sulcus broad, deep, and short, with a narrow ventral extension, anterior wall at right angles to median plane of valves, posterior wall gently inclined; sulci open at top, posterior and median sulci widening to top, anterior sulcus narrowing slightly at top; anterior wall of posterior sulcus curves rather evenly toward middle, posterior bends toward middle at almost a right angle; anterior lobe narrow, with steep walls, ending abruptly at front in narrow flattened area; median lobes broad, united ventrally below median sulcus; posterior lobe broad and not sharply defined posteriorly; wide, smooth, flat border present on anterior and ventral edges; in lateral view edges of border appear as a pronounced ridge or rim; surface of carapace finely granular.

Length, 1.1 mm.; height, 0.6 mm.

Holotype, Univ. of Missouri, 0.1000–4.

Common in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

Family THLIPSURIDAE Ulrich, 1900

Genus PLAGIONEPHRODES Morey, n. gen.

Hinge either straight or slightly convex, equal to more than half of greatest length of carapace; articulation formed by slight, sharp ridge on left valve, which fits into corresponding groove on right

valve ("tongue and groove") and by a stronger overlap of the right valve on left at ends of hinge; right valve overlaps left slightly on free edges; two strong ridges present on each valve, one in front of and one behind mid length; wide, rather thin frill or flange projects back and out from posterior edge; thick, high ridge parallels anterior edge; ridges and flanges separated from edges by narrow smooth border; other ornamentation may be present in different species.

Genotype: *Plagionephrodes uninodosus*, n. sp.

This genus is closely related to *Ropolonellus* Van Pelt and in some features to *Euglyphella* Warthin For this reason it is placed in the family Thlipsuridae.

PLAGIONEPHRODES UNINODOSUS Morey, n. sp.
Plate 28, figure 23

Carapace elongate; hinge-line very slightly convex; hinge impressed, bordered by narrow, flat area that slopes steeply in toward hinge; dorsal margin gently convex; ventral margin concave in central portion; ends rounded more or less evenly; maximum thickness at midpoint of carapace; posterior ridge long, crescentic, running from near dorsal to near ventral margin; anterior ridge short, running downward to approximately mid-line of valve, turning at right angles near dorsal margin, extending posteriorly a little past mid-length nearly parallel to hinge; node present on each valve below middle; wide, thin flange parallels posterior margin, projecting backward and outward, outer surfaces slightly crenulate; thick, high ridge parallels anterior margin; low ridge parallels concave portion of ventral margin joining anterior and posterior submarginal flange and ridge; no ridge along dorsal margin; narrow smooth border separates ridges from free edges; beveled edge of right valve slightly overlaps reciprocally beveled edge of left; surface of carapace finely granular.

Length, 1.1 mm.; height, 0.58 mm.

Holotype, Univ. Missouri, 0.1001–2.

Very rare in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

PLAGIONEPHRODES MARGINATUS Morey, n. sp.
Plate 28, figure 16

Carapace of medium size; dorsal margin and hinge straight; hinge not impressed; anterior half of carapace narrow, posterior half much wider; maximum height in posterior half; maximum thickness near mid-length; posterior marginal flange broad, smooth, originating well below dorsal angle and ending near mid-length on ventral margin; anterior marginal flange not as prominent as posterior but proportionately thicker (slightly broken in specimen figured); narrow smooth border between flanges and ridges and free edges; prominent vertical ridge in posterior half bends anteriorly at lower end, extending from below dorsal margin to near ventral margin; equally prominent ridge in anterior half, not as long as posterior ridge, extending from slightly below mid-line toward dorsal margin, turning posteriorly at a right angle near dorsum; beveled edge of right valve overlaps reciprocally beveled edge of left; surface of carapace finely granular.

Length, 1.0 mm.; height, 0.6 mm.

Holotype, Univ. Missouri, 0.1001–1.

Very rare in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

Family KIRKBYIDAE Ulrich and Bassler, 1906

Genus AMPHISSITES Girty, 1910

AMPHISSITES PECULIARIS Morey, n. sp.
Plate 28, figure 3

Carapace small, subrectangular in lateral outline; hinge slightly impressed; carapace slightly compressed near anterior dorsal angle, inflated dorsally in posterior two-thirds; dorsal margins of valves slightly convex, with greatest con-

vexity behind mid-length; anterior dorsal angle low, broadly obtuse, rounded; posterior dorsal angle fairly sharp, obtuse, a little more than a right angle; ventral margin broadly convex; anterior and posterior ends broadly rounded; anterior end more rounded than posterior; overlap of right valve on left strong at ends of dorsal contact; maximum height in posterior half; outline of carapace in dorsal view subelliptical, sides gently convex; maximum thickness at mid-length; kirkbyan pit, subcentrally located, about size of area covered by four reticulation pits; wide concave border present about free edges; low submarginal ridge between smooth border and reticulate surface of valve; smooth border along dorsal edge sloping inward toward hinge; surface of carapace, within borders, coarsely reticulate.

Length, 0.72 mm.; height, 0.53 mm.; thickness, 0.37 mm.

Syntypes, Univ. Missouri, 0.1002–4.

Common in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

AMPHISSITES GENETIVUS Morey, n. sp.

Plate 28, figure 4

Carapace small, subquadrate in lateral outline; hinge slightly impressed; carapace compressed near anterior dorsal angle, inflated in posterior two-thirds; dorsal margin straight over most of its length; ventral margin broadly convex; anterior and posterior ends broadly rounded, anterior more rounded than posterior; right valve strongly overlaps left at ends of dorsal contact; maximum height in posterior half; outline of carapace in dorsal view subelliptical; maximum thickness at mid-length; right valve overlaps left slightly on free edges; kirkbyan pit about size of area covered by four reticulation pits; wide concave border on free edges of valves; fairly broad smooth border along dorsal edge, inclined toward hinge; small marginal ridge on free edges; strong submarginal ridge on edge of wide border separating reticulate surface from border; submarginal ridge much reduced in size along dorso-anterior margin; surface of carapace covered by coarse polygonal reticulations.

Length, 0.7 mm.; height, 0.44 mm.; thickness, 0.3 mm.

Syntypes, Univ. Missouri, 0.1002–5.

Rare in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

Genus KIRKBYELLA Coryell and Booth, 1933

KIRKBYELLA SCAPHA Morey, n. sp.

Plate 28, figure 14

Outline of carapace in lateral view subquadrate; dorsal margin essentially straight; ventral margin broadly convex; anterior margin gently convex; posterior margin flattened; hinge straight, formed by slight overlap of right valve on left at dorsal angles, stronger overlap at anterior end; no overlap between dorsal angles; anterior dorsal angle sharp, a little more than a right angle; posterior dorsal angle sharp, more obtuse than anterior; posterior extremity below mid-line, anterior extremity above mid-line; maximum height in front of mid-length; maximum thickness slightly behind and below center; sides of carapace strongly convex; broad low ridge runs longitudinally on lower half of valve, curving upward somewhat toward anterior end; ridge most prominent in anterior half, merging with general surface of valve in posterior half; narrow shallow sulcus, just behind mid-length, runs from near dorsal margin to slightly above mid-line of valve; sulcus situated in a broad shallow depression in surface of valve; sulcus open at top, widening very rapidly near dorsal margin; smooth, narrow border forms a rim about free edges, present, but not raised as a rim, on dorsal edges; left valve overlaps right on free edges; amount of overlap slight; surface of carapace within smooth border shallowly reticulate.

Length, 0.83 mm.; height, 0.5 mm.

Syntypes, Univ. Missouri, 0.1001–4.

Common in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

Genus GRAPHIODACTYLUS Roth, 1929

GRAPHIODACTYLUS SPINOSUS Morey, n. sp.
Plate 28, figure 6

Carapace small, typically subrhomboidal in lateral outline; hinge-line straight; dorsal angles prominent; dorsal margin of left valve strongly convex in central portion; dorsal margin of right valve almost straight; ventral margin nearly straight, rounding to ends, inclined posteriorly; posterior end broadly rounded; anterior end obliquely rounded, smaller than posterior; maximum height in posterior half; outline of carapace in dorsal view bluntly wedge-shaped, surfaces of valves curve sharply but evenly to anterior extremity, break abruptly down to posterior extremity; maximum thickness in anterior half; right valve slightly overlaps free edges of left; strong spine on antero-ventral surface of each valve; strong keel with terminal horn on posterior margin of each valve; smaller keel on ventral and ventro-anterior edges; surface of carapace covered by more or less concentric rows of fine reticulations.

This species is distinguished from *G. arkansanus* (Girty) by the single strong spine on the antero-ventral surface of each valve. It is also proportionately shorter and thicker than *G. arkansanus*.

Length, 0.75 mm.; 0.65 mm.; height, 0.45 mm.; 0.4 mm.

Syntypes, Univ. Missouri, 0.1003–5.

GRAPHIODACTYLUS TUMIDUS Morey, n. sp.
Plate 28, figure 15

Carapace subrhomboidal in lateral outline, usually thick with broad blunt ends and gently convex sides; dorsal margins of both valves gently convex; dorsal angles of both valves low and rounded, those on right valve but slightly more prominent than those on left; ventral margin straight in central portion, curving to ends, inclined slightly posteriorly; posterior end more broadly rounded than anterior; maximum height in posterior half; outline of carapace in dorsal view subovate; maximum thickness in front of mid-length; right valve overlaps left slightly on free edges; short spine present on antero-ventral angle of each valve; surface of carapace covered by fine reticulations.

This species differs from the typical species of this genus in the more arched dorsal margin, and in the subequal cardinal angles. The more convex dorsal margin serves to distinguish it from *G. spinosus*. The figured specimen is larger and thicker than the average adult of this species.

Length, 0.89 mm.; height, 0.53 mm.

Syntypes, Univ. Missouri, 0.1003–4.

Fairly common in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

GRAPHIODACTYLUS SUBQUADRATUS Morey, n. sp.
Plate 28, figure 11

Carapace subquadrate in lateral outline; dorsal margins of valve gently convex in central portion, with fairly prominent dorsal angles on right valve; dorsal angles of left valve low and rounded; ventral margin nearly straight, inclined posteriorly; posterior end broadly rounded, with extremity slightly below mid-line; anterior end rounded, with extremity above mid-line; maximum height in posterior half; outline of carapace in dorsal view narrowly subovate, ends blunt, sides gently convex; maximum thickness in anterior half; right valve overlaps left slightly on free edges and more strongly on dorsal angles; short spine on antero-ventral surface of each valve; slight ridge borders free edges; surface of each valve covered with irregularly concentric rows of linear reticulations.

Length, 0.87, 0.9 mm.; height, 0.47, 0.5 mm.

Syntypes, Univ. Missouri, 0.1003–2.

Rare in the basal Mississippian sand-

stone 3 miles north of Williamsburg, Missouri.

GRAPHIODACTYLUS WALTERI Morey, n. sp.
Plate 28, figure 2

Carapace small, inflated in anterior half, subovate in lateral outline; margins rounded, merging without angularity; dorsal and ventral margins gently convex; anterior and posterior margins broadly and somewhat obliquely rounded; hinge-line straight between points of articulation of hinge; dorsal angles of right valves prominent, broadly rounded, much higher than the low, evenly rounded angles of left valve; maximum height in posterior half; outline of carapace in dorsal view more or less bluntly wedge-shaped, anterior end rapidly tapering, posterior end blunt; maximum thickness in front of mid-length; right valve overlaps left on free edges; several minute tubercles on antero-ventral surface of each valve; very slight ridge borders free edges; surface ornamented with more or less concentric rows of fine reticulations.

Length, 0.77 mm.; height, 0.58 mm.

Holotype, Univ. Missouri, 0.1003–3.

Rare in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

Family BAIRDIIDAE Sars, 1887

Genus BAIRDIA McCoy, 1844

BAIRDIA FRAGOSA Morey, n. sp.
Plate 28, figure 17

Carapace elongate; hinge-line equal to about one-half the total length of carapace; carapace compressed dorso-anteriorly; dorsal margin slightly arched, with a nearly straight posterior slope; ventral margin sinuate, curving abruptly to anterior end; anterior end compressed toward extremity, rather narrowly rounded; posterior end produced to sharp point; maximum height just in front of mid-length; carapace subelliptical in dorsal outline; maximum thickness just in front of center; anterior end as seen from dorsal view longer than posterior end; surface of right valve equal in height to that of left valve on posterior portion

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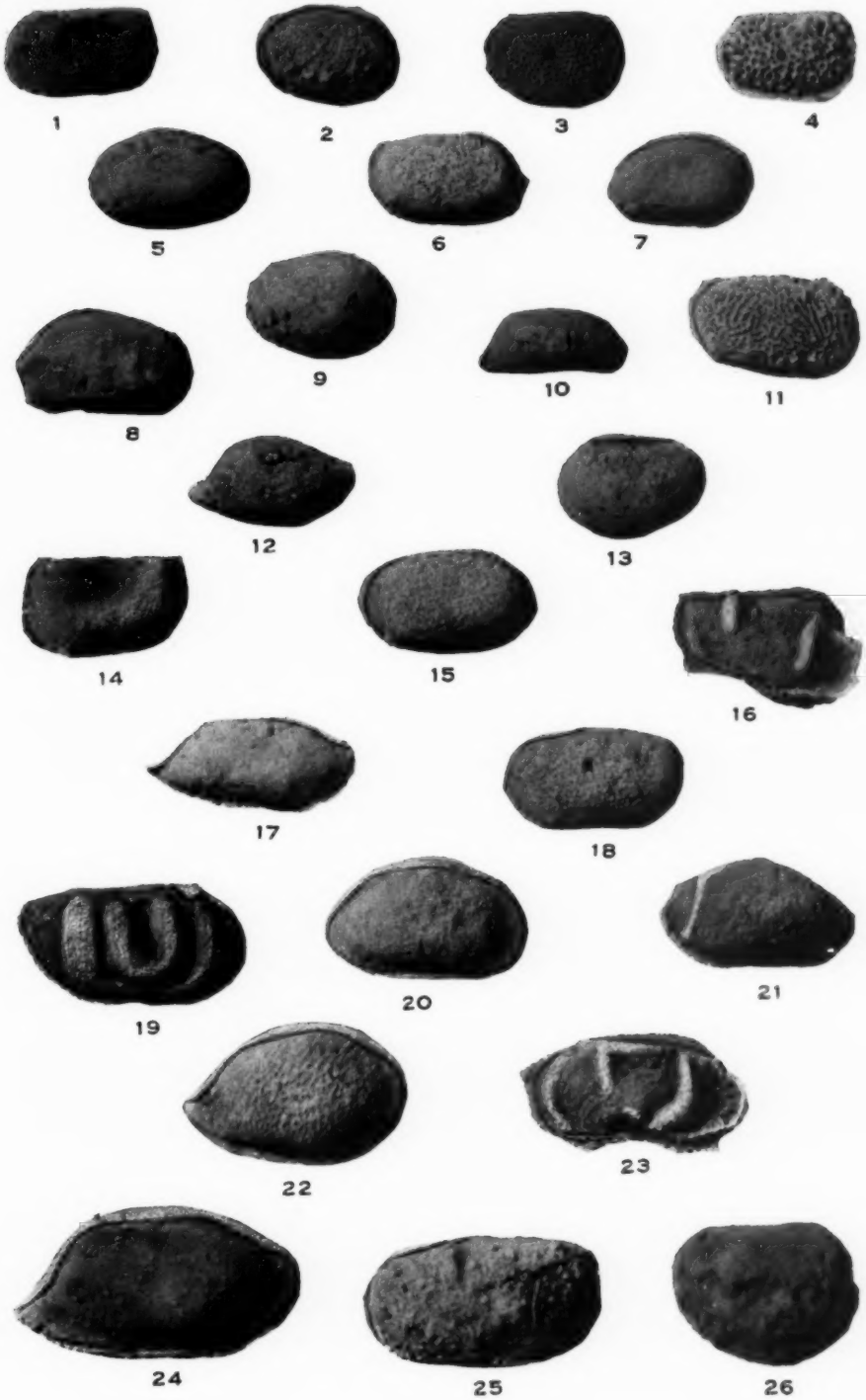
EXPLANATION OF PLATE 28

FIG. 1—*Hypotetragona impolita* Morey, n. gen. and sp. Left valve view of holotype, ×20. (p. 326)
2—*Graphiodactylus walteri* Morey, n. sp. Left valve view of holotype, ×20. (p. 322)
3—*Amphissites peculiaris* Morey, n. sp. Left valve view of holotype, ×20. (p. 319)
4—*Amphissites genetivus* Morey, n. sp. Left valve view of holotype, ×20. (p. 320)
5—*Waylandella perplexa* Morey, n. sp. Right valve view of holotype, ×20. (p. 325)
6—*Graphiodactylus spinosus* Morey, n. sp. Left valve view of holotype, ×20. (p. 321)
7—*Cytherella gunnelli* Morey, n. sp. Left valve view of holotype, ×20. (p. 325)
8—*Bythocypris incertus* Morey, n. sp. Right valve view of holotype, ×20. (p. 324)
9, 13—*Paraparchites disjunctus* Morey, n. sp. 9, Left valve view of syntype; 13, right valve view of syntype. ×20. (p. 317)
10—*Pontocypris bassleri* Morey, n. sp. Right valve view of holotype, ×20. (p. 324)
11—*Graphiodactylus subquadratus* Morey, n. sp. Left valve view of holotype, ×20. (p. 321)
12—*Bairdia gibbera* Morey, n. sp. Right valve view of holotype, ×20. (p. 323)
14—*Kirkbyella scapha* Morey, n. sp. Right valve view of holotype, ×20. (p. 320)
15—*Graphiodactylus tumidus* Morey, n. sp. Left valve view of holotype, ×20. (p. 321)
16—*Plagionephrodes marginatus* Morey, n. sp. Left valve view of holotype, ×20. (p. 319)
17—*Bairdia fragosa* Morey, n. sp. Right valve view of holotype, ×20. (p. 322)
18, 25—*Sulcella decora* Morey, n. sp. 18, Right valve view of syntype (male); 25, left valve view of syntype (female). ×20. (p. 325)
19—*Dizygopleura mehli* Morey, n. sp. Left valve view of holotype, ×20. (p. 318)
20—*Bairdia pecki* Morey, n. sp. Right valve view of holotype, ×11. (p. 323)
21—*Healdia subcarinata* Morey, n. sp. Right valve view of holotype, ×20. (p. 324)
22—*Bairdia magnacurta* Morey, n. sp. Right valve view of holotype, ×20. (p. 323)
23—*Plagionephrodes uninodosus* Morey, n. sp. Left valve view of holotype, ×20. (p. 319)
24—*Bairdia subparallela* Morey, n. sp. Right valve view of holotype, ×20. (p. 323)
26—*Paraparchites nicklesi* (Ulrich). Left valve view of hypotype, ×20. (p. 317)



Morey, Mississippian Ostracoda

of dorsal slope, left valve elsewhere peripheral to right; overlap of left valve on right slight; surface of carapace smooth.

Length, 0.97, 1.03 mm.; height, 0.45, 0.45 mm.; thickness, 0.33, 0.38 mm.

Syntypes, Univ. Missouri, 0.1004–3.

Fairly common in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

BAIRDIA GIBBERA Morey, n. sp.
Plate 28, figure 12

Carapace small; hinge short, equal to about one-fourth total length of carapace slightly impressed, inclined very slightly to posterior; dorsal portion of carapace inflated, appearing in lateral view as a conspicuous hump; valves equal in height on inflated portion; anterior dorsal slope almost straight; posterior dorsal slope concave; ventral margin gently and evenly convex, curving up rather abruptly to anterior end; anterior end narrowly rounded; posterior end acute; maximum height behind mid-length; carapace broadly subovate in dorsal outline; maximum thickness at mid-length; overlap of left valve upon edges of right slight, strongest on antero-dorsal and ventral edges; surface of carapace smooth.

Length, 0.82 mm.; height, 44 mm.; thickness, 0.4 mm.

Holotype, Univ. Missouri, 0.1004–5.

Very rare in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

BAIRDIA MAGNACURTA Morey, n. sp.
Plate 28, figure 22

Carapace above medium size, short in comparison to height and thickness; hinge straight, inclined toward posterior; slightly less than two-thirds total length of carapace; dorsal margin arched, fairly evenly convex, dorsal limb shorter and more convex than posterior; anterior end short, compressed, margin obliquely rounded; posterior end rather short and acute; ventral margin flattened; maximum height in front of mid-length; sides strongly convex; maximum thickness at center of carapace; left valve overlaps right on all margins, only slightly on ends strongly on dorsal side of acute posterior end and along flattened portion of ventral margin.

Length, 1.15 mm.; height, 0.7 mm.; thickness, 0.6 mm.

Holotype, Univ. Missouri, 0.1007–1.

Rare in the basal Mississippian sandstone 3 miles north of Williamsburg; Easley; Providence; Brown's; Danville, Missouri.

BAIRDIA PECKI Morey, n. sp.
Plate 28, figure 20

Carapace large; subtrapezoidal in lateral outline; hinge short, slightly more than one-third total length of carapace, inclined slightly to posterior; dorsal margin strongly arched, anterior and posterior slopes about equal in convexity; ventral margin straight over most of length, curving to ends; anterior end broadly rounded, strongly compressed near extremity; posterior end shorter than anterior and rather narrowly rounded, strongly compressed laterally near extremity; outline of carapace in dorsal view more or less subelliptical; maximum thickness slightly behind and above center; maximum height in front of mid-length; left valve peripheral to right on all margins, actual overlap slight, strongest on ventral margin; surface of carapace smooth.

Length, 1.78 mm.; height, 1.08 mm.; thickness, 0.86 mm.

Syntypes, Univ. Missouri, 0.1005–2.

Fairly abundant in the basal Mississippian sandstone 3 miles north of Williamsburg; Easley, Missouri.

BAIRDIA SUBPARALLELA Morey, n. sp.
Plate 28, figure 24

Carapace large; hinge equal to slightly less than one-half total length of carapace, inclined slightly to posterior; dorsal margin broadly convex; anterior limb of dorsal margin essentially straight; posterior limb curves down abruptly and

steeply to posterior end; ventral margin gently convex with slight concavity just in front of mid-length; anterior end long, laterally compressed toward extremity; posterior end short, acute, somewhat compressed laterally; maximum height at mid-length; sides of carapace gently convex; maximum thickness just in front of mid-length; overlap of left valve upon right slight, strongest on steeply inclined postero-dorsal slope, at slight concavity in ventral margin just in front of mid-length, and on anterior limb of dorsal margin; surface of carapace smooth.

This species resembles *B. permagna* Geis, but can be easily distinguished by its greater thickness throughout its length and by its comparatively longer hinge-line.

Length, 1.43 mm.; height, 0.8 mm.; thickness, 0.5 mm.

Holotype, Univ. Missouri, 0.1007–2.

Rare in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

Genus Bythocypris Brady, 1880

Bythocypris incertus Morey, n. sp.
Plate 28, figure 8

Carapace subpediform in lateral outline; dorsal margin arched, anterior slope long and gently convex, posterior slope curves abruptly down to posterior extremity; anterior end broadly rounded; posterior end narrowly rounded, with greatest extremity below mid-line of carapace; maximum height behind mid-length; outline of carapace in dorsal view subelliptical; maximum thickness at center; left valve overlaps right strongly on dorsal and ventral edges, less strongly elsewhere; left valve peripheral to right on all margins; surface of carapace smooth.

The posterior end and a portion of the dorso-anterior slope of the dorsal margin of the holotype and only specimen are broken off. A horizontally elongate pit in the posterior half is an impression of a sand grain.

Length, 0.92 mm.; height, 0.64 mm.; thickness, 0.42.

Holotype, Univ. Missouri, 0.1005–5.

Very rare in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

Genus Pontocypris Sars, 1886

Pontocypris bassleri Morey, n. sp.
Plate 28, figure 10

Carapace small and elongate; hinge slightly impressed, equal to slightly more than one-half total length of carapace; dorsal margin broadly convex; ventral margin gently convex, with a concavity just in front of mid-length; anterior end narrowly rounded; posterior end acuminate; maximum height at mid-length; outline of carapace in dorsal view narrowly subovate; maximum thickness through center; carapace strongly inflated in dorsal half below posterior half of hinge; left valve overlaps right on ventral margin and posterior end; surface of carapace smooth.

Length, 0.75 mm.; height, 0.35 mm.; thickness, 0.3 mm.

Holotype, Univ. Missouri, 0.1006–3.

Rare in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

Genus Healdia Roundy, 1926

Healdia subcarinata Morey, n. sp.
Plate 28, figure 21

Carapace small; dorsal margin well arched, limbs flattened; ventral margin slightly concave in central portion; posterior end more broadly rounded than anterior; maximum height at mid-length; outline of carapace in dorsal view subovate; maximum thickness just behind mid-length; left valve overlaps right slightly on all edges except along hinge; smooth keels present on anterior and posterior margins; ridge and two spines present on each valve, lower spine prominent, upper spine obscure; a large pitted area, apparently the muscle spot, on each valve, bordered posteriorly by the

ridge; surface of carapace elsewhere smooth.

Length, 0.95 mm.; height, 0.5 mm.; thickness, 0.45 mm.

Syntypes, Univ. Missouri, 0.1004–1.

Common in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

Genus WAYLANDELLA Coryell and Billings, 1932

WAYLANDELLA PERPLEXA Morey, n. sp.
Plate 28, figure 5

Carapace small; subovate in lateral outline; dorsal margin broadly arched, posterior slope curving more abruptly to extremity than anterior; ventral margin broadly convex; ends broadly rounded; hinge about one-fourth total length of valves; maximum height just behind mid-length; outline of carapace in dorsal view subovate; maximum thickness through center; left valve overlaps right slightly on all edges except between points of articulation of hinge; a short ridge, usually broken off, begins at midline of valve and terminates on postventral surface in a short spine; surface of carapace smooth.

Length, 0.81 mm.; height, 0.5 mm; thickness, 0.42 mm.

Syntypes, Univ. Missouri, 0.1004–2.

Rare in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

Family CYTHERELLIDAE Sars, 1866

Genus CYTHERELLA Jones, 1849

CYTHERELLA GUNNELLI Morey, n. sp.
Plate 28, figure 7

Carapace small; subovate in lateral outline; dorsal margin strongly convex, anterior slope long and gently convex, posterior slope short and strongly convex; ventral contact convex with nearly straight portion; posterior end more broadly rounded than anterior; greatest extension of posterior end above that of anterior end; postero-ventral margin gently convex, appearing truncate in lateral view; maximum height at mid-length; outline of carapace in dorsal view wedge-shaped; maximum thickness in posterior half; right valve overlaps left fairly evenly along entire edge of valve; surface of carapace smooth.

The small pit on the figured specimen just in front of the mid-length is not a natural feature but is the impression of a sand grain.

Length, 0.75 mm.; height, 0.4 mm.

Syntypes, Univ. Missouri, 0.1006–4.

Fairly common in the basal Mississippian sandstone 3 miles north of Williamsburg, Missouri.

Genus SULCELLA Coryell and Sample, 1932

SULCELLA DECORA Morey, n. sp.
Plate 28, figures 18, 25

Carapace subrectangular in lateral outline; dorsal margin gently convex; hinge-line slightly arched, hingement formed by "lip-and-lip" overlap, upper "lip" on right valve; edge of right valve thicker on anterior third of dorsal edge; beveled edge of right valve overlaps reciprocally beveled edge of left on free edges; ventral margin almost straight in central portion; anterior end broadly and evenly rounded; posterior end subangular; posterior half of dorsum channeled, strongly so in females and slightly so in males; maximum height near mid-length; outline of carapace in dorsal view wedge-shaped; maximum thickness in some specimens near posterior end (females) and in other near mid-length (males); a sharp low, submarginal ridge, strongest on the ends, parallels free edges; well defined pit just in front of mid-length, varies from equidimensional to length twice width; surface of carapace smooth. Females are much larger and more numerous than the males.

Length, (large female) 1.2 mm.; height, 0.65 mm.

Syntypes, Univ. Missouri, 0.1002–2 0.1002–3.

Common in the basal Mississippian

sandstone 3 miles north of Williamsburg, Missouri.

Genus HYPOTETRAGONA Morey, n. gen.

Carapace in lateral view subrectangular; hinge straight, apparently formed by stronger overlap of right valve on left at posterior end of hinge-line and on anterior third of hinge; maximum thickness at center in males and in anterior half in females; posterior end in females thick and angular; sulcus present in front of mid-length, running from near dorsal margin to mid-line; sharp, low ridge parallels free margins, separated from edge by narrow, smooth border; surface of carapace inside ridge reticulate.

Genotype: *Hypotetragona impolita* Morey, n. sp.

HYPOTETRAGONA IMPOLITA Morey, n. sp.
Plate 28, figure 1

Carapace subrectangular in lateral outline; hinge straight; dorsal margin straight or very slightly convex; ventral margin gently convex with nearly straight central portion; right valve apparently strongly overlaps left on anterior third of dorsal margin; posterior half of dorsum channeled, in female specimens strongly, in male specimens slightly; maximum height in posterior half; outline of carapace wedge-shaped in females in dorsal view, narrowly subovate in males; maximum thickness in posterior half in females and at mid-length in males; small, sharp ridge or carina borders free edges of valve, separated by smooth, narrow border from edges; sulcus in front of mid-length runs from near dorsal margin to mid-line; surface of carapace reticulate.

Length (female specimen), 0.9 mm.; height, 0.5 mm.

Syntypes, Univ. Missouri, 0.1001–5, 0.1002–1.

Rare in the basal Mississipipian sandstone 3 miles north of Williamsburg, Missouri.

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LARGER FORAMINIFERA FROM THE MOODY'S BRANCH MARL, JACKSON EOCENE, OF TEXAS, LOUISIANA, AND MISSISSIPPI[1]

DONALD W. GRAVELL and MARCUS A. HANNA
Paleontologists, Gulf Production Company, Houston, Texas

ABSTRACT

In this paper the larger foraminifera now known from the Moody's Branch marl of Texas Louisiana, and Mississippi are described and figured. *Camerina jacksonensis* and *Camerina moodybranchensis* are described and figured as new species. *Operculina vaughani* Cushman and *Discocyclina flintensis* (Cushman) are refigured and additional descriptions given. *Discocyclina* sp. A and B are figured. *Lepidocyclina* (*Lepidocyclina*) *mortoni* Cushman is refigured and additional description given. The geographical distribution of the species listed is discussed.

The Tertiary sediments of the Gulf Coastal Plain are, in general, a homoclinal series of sands and shales or clays. Certain beds are predominantly glauconitic. In the eastern portion of the region, limestones are common, particularly in the Jackson (Eocene) and Oligocene. The maximum thickness of the Tertiary beds is great, although the exact thickness is not known. In southern Louisiana the post-Oligocene beds have a thickness of at least 10,000 feet. In Texas, the Jackson and Oligocene beds have a thickness of at least 6,000 feet. In Texas north of Houston 3,000 feet of upper and middle Claiborne deposits have been penetrated in wells. In the lower coastal plain no reliable estimate can be made for the thickness of the lower part of the Eocene, although it is believed to be great.

In Texas and western Louisiana the section from the top of the middle Claiborne to Recent is almost devoid of sedimentary fossiliferous limestone. Thin beds of limestone are often reported in wells, but these, for the most part, are lime-cemented sands. In certain areas the *Heterostegina* zone (1, 10)[2] referred to both the Oligocene and Miocene, attains the composition and hardness of a limestone. With this exception, however, the section is remarkably free from limestone.

In eastern Louisiana and Mississippi the *Heterostegina* zone, the lower part of the Chickasawhay group (14), and the Vicksburg group (3) are predominantly marls and limestones.

The economic paleontologist is confronted with the problem of correlating the beds of this series of sediments, both on the surface and beneath the surface, throughout the area in which the beds occur. We have been particularly interested in

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[2] Numbers refer to bibliography at end of the paper.

the area from the Rio Grande to Alabama and Florida. To those familiar with the variation in sediments having such a great areal and subsurface extent, particularly since the beds range in origin from nonmarine to marine as well as increasing rapidly in thickness toward the coast, the magnitude of the problem is apparent. For this reason most paleontologists attempting correlations within this area have adopted zonation (11) as the tool for correlation rather than attempting to carry formational names through the maze of sedimentational complexity. Several zones have been described and many more are in general use in the various laboratories.

The larger foraminifera of the Moody's Branch Marl are found within a zone of less than 50 feet extending from Waller County, Texas, eastward beyond the eastern side of Mississippi at least into Florida. Within this area they can be traced to a depth of at least 7,000 feet. Since these foraminifera are large, readily observable, and usually fairly abundant throughout the area cited, they are considered to be worthy of review in this paper.

THE MOODY'S BRANCH MARL

In 1914 Deussen (7) summarized the distribution of the Jackson formation as follows:

> The formation (Jackson) to be described was named by Conrad in 1856 after Jackson, the capitol of Mississippi, where the beds are characteristically exposed (2). In 1869, Hopkins traced the formation across Louisiana as far as the Red River (9). Veatch was the first to announce the existence of the formation in Texas, which he did in 1902 (17).

Referring to the type locality of the Jackson formation, Hilgard (8, p. 128) stated:

> The lower portion is formed by from 10 to 20 feet of sandy strata, commonly of a bluish tinge, and containing green sand grains. It is this lower bed (Moody's Branch), cropping out on the banks of Pearl River, at Jackson, which has furnished the fossils described by Conrad (2), and figured in Prof. Wailes' Report. . . .

In addition Hilgard (8, p. 131) gave the thickness and character of the beds at Moody's Branch and McNutts Hills. Lowe (12) in 1915 again mentioned the excellent preservation of the fossils in the Moody's Branch marl at the type locality when he stated:

> Beneath these clays, outcropping on Moody's Branch immediately south of Belhaven College grounds, is a bed of dark-blue highly fossiliferous sand. The beautifully preserved fossils of cabinets come from this classic collecting ground.

Many good exposures of Moody's Branch have been mentioned in the literature. Material from a few of the more classic localities has been examined for this paper. With the exception of the locality in sec. 35, T. 6 N., R. 1 E., Hinds County, Mississippi, the surface localities cited in this paper, Garland Creek, Moody's Branch, Gibson's Landing, Grandview Bluff, and Montgomery Bluff, have long been known and well described.

GEOGRAPHICAL DISTRIBUTION OF THE MOODY'S BRANCH LARGER FORAMINIFERA

Figure 1 shows the location of 17 localities cited in this paper, but these are only a few of the localities from which the larger foraminifera of the Moody's Branch have been recorded. The localities have been noted about 25 miles southwest of Loc. 1, in the Stanolind Oil and Gas Company's No. 1 Thorp located in Lot 100 of the Houston and Texas Central Railroad Company's Block 1, Waller County, Texas, as well as in the Stanolind Oil and Gas Company's No. 1 Manor, located in Lot 93 of the same block.

FIG. 1—Map showing localities from which larger foraminifera of the Moody's Branch marl are described.

selected for citation in order to show the general distribution of these particular fossils from west of Houston, Texas, to the Mississippi-Alabama line. A great many more localities could be added within this area if it were believed such addition would add materially to the value of the paper.

Since the sketch map was made the occurrence of larger foraminifera in the Moody's Branch has been

To date we have not found larger foraminifera in the Moody's Branch southwest of the Thorp well. The green sands so characteristic of this member of the Jackson are present. Whether our lack of records is due to the absence of these fossils or to insufficient samples, is not definitely known. We have examined many samples from southwest of the Thorp well, and because of this are inclined to believe that these fossils are not

present, at least in any abundance, in the south coastal portion of Texas.

It is to be noted in the check list that *Camerina moodybranchensis* Gravell and Hanna is the species most common in the western part of the central-eastern Louisiana, it is very abundant. *Camerina jacksonensis* Gravell and Hanna, is rare in Texas, but increases in abundance in Louisiana and Mississippi. With the increase in abundance of *C. jackson-*

Distribution of Larger Foraminifera from the Moody's Branch Marl.

Locality	1a	1b	2	3	4a	4b	5a	5b	6a	6b	6c	7	8a	8b	9a	9b	10	11a	11b	12	13	14	15	16	17
Camerina jacksonensis	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	×	×	×	×	×
Camerina moodybranchensis	×	×	×	×	×	×	×	×	—	×	×	×	×	—	—	—	×	—	—	—	—	—	—	—	—
Operculina vaughani	—	—	—	—	—	—	×	—	—	×	—	—	×	—	×	—	×	×	—	×	×	×	×	×	—
Lepidocyclina (Lepidocyclina) mortoni	—	—	—	—	—	—	—	—	—	—	—	—	×	—	×	—	×	—	×	×	×	×	×	×	×
Discocyclina flintensis	—	—	—	—	—	—	×	—	×	—	—	—	—	—	×	—	—	—	×	×	—	—	—	—	—
Discocyclina sp. A	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×	×	×	—	—
Discocyclina sp. B	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—

Loc. 1. Stanolind Oil and Gas Co.-Amerada Petroleum Co. No. 2 Wm. Theis, located in the northeast part of the John H. Edwards headright, Tom Ball Field, Montgomery County, Texas; *a*, core 5,216–5,217 ft., *b*, core 5,218–5,219 ft.

Loc. 2. Van McPhail No. 1 Dunham, located near the center of the George H. Delesdenier headright, Harris County, Texas; core 6,210 ft.

Loc. 3. Houston Oil Co.-Heep Oil Corp. No. 1 R. L Cartwright, located in the John Davis headright, Conroe Field, Harris County, Texas; top of core 3,917–3,936 ft.

Loc. 4. Turnbull and Irwin No. 1 Aylor, located in the northeast part of the Elijah Votaw headright, Montgomery County, Texas; *a*, bottom of core 5,069–5,089 ft., *b*, core 5,089–5,099 ft.

Loc. 5. Piedmont Oil Co., No. 1 Foster Lumber Co. Located near the center of the George Taylor headright, San Jacinto Co. Texas; *a*, core 4,421–4,431 ft., *b*, core 4,431–4,441 ft.

Loc. 6. Shell Petroleum Corp. No. 1 Munson, located in the southeast part of the Augustine Viesca 7 Leagues headright, Livingston Field, Polk County, Texas; *a*, top of core 4,247–4,257 ft., *b*, middle of core 4,247–4,257 ft., *c*, bottom of core 4,247–4,257 ft.

Loc. 7. L. W. Wentz No. 1 Longbell Lumber Co., located in the western part of the James Seals headright, Tyler County, Texas; core 4,098–4,099 ft.

Loc. 8. Turnbull and Irwin No. 1 McShane, located in the north-central part of the W. B. Green headright, Jasper County, Texas; *a*, cuttings 1,573–1,593 ft., *b*, cuttings 1,735–1,755 ft.

Loc. 9. American Lumber Company No. 1 Hennigan, located in sec. 36, T. 2 S., R. 12 W., Beauregard Parish, Louisiana; *a*, core 4,753 ft., *b*, core 4,776 ft. (?).

Loc. 10. Montgomery Bluff, from the basal 6 inches of the Moody's Branch exposed in the east bank of the Red River, one-half mile below the ferry landing, sec. 20, T. 8 N., R. 5 W., near Montgomery, Grant Parish, Louisiana.

Loc. 11. Hindman No. 1 Longbell Lumber Co., located in sec. 30, T. 2 N., R. 2 W., Rapides Parish, Louisiana; *a*, cuttings 3,450–3,480 ft., *b*, cuttings 3,481–3,511 ft.

Loc. 12. Gibson Landing on the Ouachita River, sec. 11, T. 12 N., R. 4 E., Caldwell Parish, Louisiana.

Loc. 13. Grandview Bluff on the Ouachita River, sec. 18, T. 12 N., R. 5 E., Caldwell Parish, Louisiana.

Loc. 14. Type Moody's Branch, east bank of Moody's Branch, about 250 feet south of the junction of Hazel Street and Poplar Boulevard, being about one-fourth mile south of Belhaven College, in the town of Jackson, Hinds County, Mississippi.

Loc. 15. Gulf Refining Company No. 1 Misterfelt, sec. 2, T. 4 N., R. 1 E., Hinds County, Mississippi.

Loc. 16. Surface outcrop in sec. 35, T. 6 N., R. 1 E., Hinds County, Mississippi.

Loc. 17. Surface outcrop in south bank of Garland Creek, northwest corner of sec. 28, T. 1 N., R. 16 E., Clark County, Mississippi.

range of these larger foraminifera. In many core samples it is very abundant. *Operculina vaughani* Cushman is fairly rare in the western part of the occurrence of this fossil in Texas, but increases in abundance through eastern Texas and Louisiana. At Loc. 12, Gibson's Landing in

ensis and *O. vaughani*, *C. moodybranchensis* decreases, and it has not been noted east of central Louisiana.

The type locality of *Lepidocyclina* (*Lepidocyclina*) *mortoni* Cushman is Montgomery Bluff, Louisiana, Loc. 10. It has been found only sparingly in Texas, but increases in

abundance to the eastward. At Gibson's Landing, Louisiana, Loc. 12, it is abundant.

Discocyclina flintensis (Cushman) has been found rarely from Loc. 5 in San Jacinto County, Texas, to Loc. 12 Gibson's Landing, Caldwell Parish, Louisiana. *Discocyclina* sp. A has been found rarely at Loc. 9 in Beauregard Parish, Louisiana, to Loc. 15 in Hinds County, Mississippi. *Discocyclina* sp. B has been found only at Loc. 8 in Jasper County, Texas.

The most striking variation in this fossil assemblage is the abundance of *Camerina moodybranchensis* through Texas and western Louisiana, but with the decrease of this species to the eastward *Camerina jacksonensis* and *Operculina vaughani* increase in abundance.

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DESCRIPTION OF SPECIES

Family CAMERINIDAE

Genus CAMERINA Brugière, 1792

CAMERINA JACKSONENSIS Gravell and Hanna, n. sp.

Plate 29, figures 1–5, 7–8, 10–11, 13–14

Test small, completely involute, thickly lenticular, many specimens nearly perfectly lenticular, others have a poorly developed flange; center of test marked by a large boss of slightly raised clear shell material. Diameter up to 2.3 mm., thickness about 0.9 mm. Sutures of clear shell material, not raised, rather indistinct, ornamented by beads of clear shell material of which there are from two to seven along a suture. Sutures radiate from the central boss, gently curved to the point where they pass over the periphery of the previous whorl, then curve forward sharply and then bend backward gradually until the periphery where their backward curvature becomes sharp. Periphery of test rounded.

Horizontal sections show the initial chamber to be globular, about 50 μ in diameter; second chamber kidney-shaped, about 60 to 100 μ; the following chambers are of the normal *Camerina* type. Adult specimens composed of four and one-half to five closely coiled whorls which increase slowly in width. The number of chambers and the width of the respective whorls is as follows:

First whorl about 100μ wide, composed of 6 chambers.
Second whorl about 200μ wide, composed of 11 chambers.
Third whorl about 280μ wide, composed of 14 chambers.
Fourth whorl about 330μ wide, composed of 16–17 chambers.
Fifth whorl about 380μ wide, composed of 20–22 chambers.

Camerina jacksonensis is distinct from other American species, being characterized by its small size and especially by its beaded sutures.

Syntypes from Loc. 16, associated with *Operculina vaughani* Cushman, *Lepidocyclina* (*Lepidocyclina*) *mortoni* Cushman, and a single specimen of *Discocyclina* sp. A, found also at Locs. 4, 9, 13, 14, 15, and 17.

Upper Eocene, Moody's Branch member of the Jackson formation.

The syntypes of this species will be deposited in the U. S. National Museum.

CAMERINA MOODYBRANCHENSIS Gravell and Hanna, n. sp.
Plate 29, figures 15, 22–24

Test small, lenticular, completely involute, relatively thick; diameter up to 3.5 mm.; thickness from about 0.8 to 1.2 mm. or about one-third to one-fourth the diameter; many specimens nearly perfectly lenticular, others have a poorly developed flange whose width varies from a mere vestige in some specimens to as much as 0.75 mm. in others; periphery of test sharply rounded, almost truncate.

Sutures of clear shell material, smooth, not raised, only those of the last formed whorl visible on the surface; some of the sutures do not extend entirely to the center of the test, as many as two to four often converge and but one of this group reach the center (Pl. 29, figs. 22 and 23), thus producing a branching pattern. The center of the test is marked by an irregular area of clear shell material which is formed by the merging of the septa; sutures radiate from center but slightly curved until near the periphery where they bend backward sharply; from 28 to 30 chambers in the last whorl of adult specimens.

Horizontal sections show the embryonic apparatus to be composed of a globular initial chamber from 60 to 90 μ in diameter, followed by a kidney-shaped second chamber whose greater diameter is from 90 to 120 μ, lesser diameter from 50 to 80 μ. No microspheric specimens were observed.

Adult specimens composed of five to five and one–half whorls, which slowly increase in width. The number of chambers and the width of the respective whorls is as follows:

First whorl about 100μ wide, composed of 6 chambers.
Second whorl about 200μ wide, composed of 13 chambers.
Third whorl about 300μ wide, composed of 18 to 19 chambers.
Fourth whorl about 420μ wide, composed of 23 to 24 chambers.
Fifth whorl about 500μ wide, composed of 28 to 30 chambers.

Camerina moodybranchensis resembles *Camerina parvula* (Cushman)(4) from the upper Eocene of St. Bartholomew, West Indies, being about the same size but less inflated and less heavily constructed.

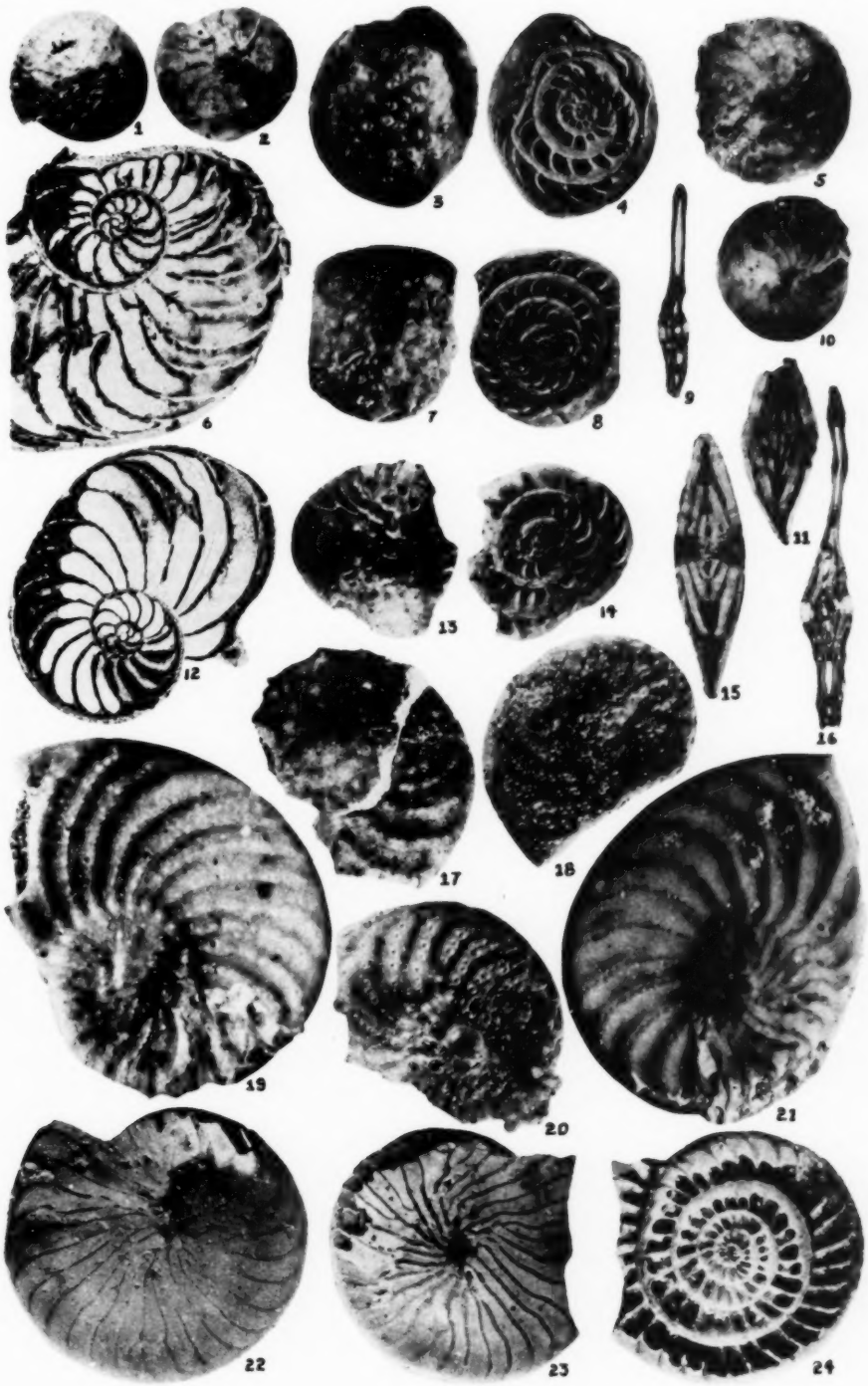
Syntypes from Loc. 10, associated with *Operculina vaughani* Cushman and *Lepi-*

EXPLANATION OF PLATE 29
All figures ×11.9

FIGS. 1–5, 7, 8, 10, 11, 13, 14—*Camerina jacksonensis* Gravell and Hanna, n. sp. 1, Syntype (used in accordance with Charles Schuchert, 13) (Loc. 16). 2, 3, Syntypes (Loc. 16). 4, Syntype; half section of specimen shown in figure 3; photographed in reflected light (Loc. 16). 5, 7, 10, 13, Syntypes (Loc. 16). 8, Syntype; half section of specimen shown in figure 7; photographed in reflected light (Loc. 16). 11, Syntype; half section; photographed in reflected light (Loc. 16). 14, Syntype; half section of specimen shown in figure 13; photographed in reflected light (Loc. 16). (p. 331)

6, 9, 12, 16–21—*Operculina vaughani* Cushman. 6, 9, 12, 16, Hypotypes; thin sections of specimens from 27 feet above the base of the Moody's Branch (Loc. 12). 17, Hypotype (Loc. 16). 18, Hypotype; specimen from the top part of a core from 4,321–4,331 feet (Loc. 5). 19, Hypotype; specimen from 27 feet above the base of the Moody's Branch (Loc. 12). 20, Hypotype (Loc. 10). 21, Hypotype; specimen from 27 feet above the base of the Moody's Branch (Loc. 12). (p. 334)

15, 22–24—*Camerina moodybranchensis* Gravell and Hanna, n. sp. 15, Syntype; thin section (Loc. 10). 22, Paratype (Loc. 6). 23, Syntype (Loc. 10). 24, Syntype; half section of specimen shown in figure 23; photographed in reflected light (Loc. 10). (p. 332)



Gravell and Hanna, Eocene Foraminifera

docyclina (*Lepidocyclina*) *mortoni* Cushman; paratypes from Locs. 5 and 6; also occurs at Locs. 1, 2, 3, 4, 7, and 8.

Upper Eocene, Moody's Branch member of the Jackson formation.

The syntypes of this species will be deposited in the U. S. National Museum.

Genus OPERCULINA d'Orbigny, 1826

OPERCULINA COOKEI Cushman

Operculina cookei CUSHMAN, *1921*, U. S. Geol. Survey, Prof. Paper 128, pp. 127–128, pl. 18, figs. 1–2.—VAUGHAN, *1924*, Geol. Soc. America, Bull., vol. 35, no. 4, p. 788; *1928*, Florida Geol. Survey, 19th Ann. Rept., p. 157.

Cushman gave the type locality of *Operculina cookei* as follows:

Type specimen from U. S. G. S. station 7116, bluff on west bank of Flint River, 1¾ miles above the Georgia Southwestern and Gulf railroad bridge near Oakfield, Lee County, Georgia, bed No. 1 of section (base of Bluff); C. W. Cooke collector; Ocala limestone.

Cushman (6, p. 128) reported the following occurrence of *Operculina cookei:*

A single, very beautifully preserved specimen showing the exterior was obtained at U. S. G. S. Station 6458, in the Moody's Branch calcareous marl member of the Jackson, at Moody's Branch, Jackson, Mississippi; C. W. Cooke collector.

We have observed no specimens of *Operculina cookei* in our samples from the Moody's Branch member of the Jackson Eocene.

OPERCULINA OCALANA Cushman

Operculina ocalana CUSHMAN, *1921*, U. S. Geol. Survey, Prof. Paper 128, p. 129, pl. 19, figs. 4–5.—VAUGHAN, *1924*, Geol. Soc. America, Bull., vol. 35, no. 4, p. 788; *1928*, Florida Geol. Survey, 19th Ann. Rept., pp. 155–58.

Cushman described *Operculina ocalana* as follows:

Test complanate, much compressed, composed of two to three coils, the last with 16 to 18 chambers; sutures raised, confluent in the center, somewhat rounded, the area between concave and smooth; chambers three to four times as long as wide; central area of the test umbonate; periphery somewhat raised by a thickening in which the raised sutures terminate. Length as much as 6 mm.

Geologic occurrence, Ocala limestone and Jackson formation.

Type specimen (U. S. N. M. catalogue No. 328249) from U. S. G. S. station 6747, Steamboat Point, on west side of Sepulga River at sharp bend near middle of sec. 20, T. 3 N., R. 13 E., Escambia County, Alabama. C. W. Cooke collector.

In his description of *O. ocalana* Cushman stated that the last coil had from 16 to 18 chambers, whereas 23 chambers are shown by the figure of the type specimen (Pl. 19, fig. 5). Cushman's Plate 19, figure 4, which is of a specimen from the type locality, has at least 20 chambers in the last coil.

It is evident that *Operculina ocalana* has from 20 to 23 chambers in the last coil rather than from 16 to 18.

Cushman (6, p. 129) reported the occurrence of *Operculina ocalana* in the Moody's Branch calcareous marl member at Moody's Branch, Jackson, Florida, with *O. cookei* Cushman and *Lepidocyclina fragilis* Cushman. In the above sentence the locality was obviously intended to be Moody's Branch, Jackson, Mississippi, rather than Moody's Branch, Jackson, Florida.

We have observed no specimens of *Operculina cookei* or *Lepidocyclina* (*Nephrolepidina*) *fragilis* in our samples from the Moody's Branch marl, Moody's Branch, Jackson, Mississippi. A few specimens of an *Operculina* which we have identified as *Operculina vaughani* Cushman are present in our material associated with a few specimens of *Lepidocyclina* (*Lepidocyclina*) *mortoni* Cushman, *Camerina jacksonensis* Gravell and Hanna, n. sp., and a single specimen of *Discocyclina* sp. A. Our specimens of *Operculina* resemble *Operculina ocalana* in size, number of chambers, and general form, but appear to differ in that they are more delicately constructed, the walls of the test being thinner.

OPERCULINA VAUGHANI Cushman
Plate 29, figures 6, 9, 12, 16–21

Operculina vaughani CUSHMAN, *1921*, U. S. Geol. Survey, Prof. Paper 128, p. 128, pl. 19, figs. 6–7.—VAUGHAN, *1924*, Geol. Soc. America, Bull., vol. 35, no. 4, p. 788.
Operculina oliveri ELLISOR, *1933*, Am. Assoc. Petroleum Geologists, Bull., vol. 17, no. 11, pp. 1299, 1301, pl. 2, fig. 15.

Unfortunately the type specimen as well as the other figured specimen of *Operculina vaughani* are accidental sections in a limestone matrix. The characteristics of the surface are not determinable from the type, and as the surface ornamentation is an important specific feature some of the characteristics of the figured type specimen of *Operculina vaughani* are rather uncertain.

Cushman's description of *Operculina vaughani* is as follows:

> Test coiled, planospiral, very thin, composed of about three coils rapidly increasing in breadth; chambers numerous, 20 to 22 in the last formed coil, fairly constant in size and shape, in the adult the length of the chambers five to six times the height, each chamber gradually increasing in height from the proximal end, the maximum height near the distal end; sutures usually starting from the proximal end in a nearly straight radial line and keeping so for about one-third the length, then gently rounded backward toward the periphery, near which the rate of curvature is abruptly increased. Length of adult specimen 7 to 8 mm.
>
> Geologic occurrence, Ocala limestone and Brito formation.
>
> Type specimen from U. S. G. S. station 3617, Muckafoonee Creek, Albany, Ga.; T. Wayland Vaughan, collector.

The Moody's Branch of Mississippi, Louisana, and Texas contains a species of *Operculina* which checks *Operculina vaughani* Cushman in the number of whorls, chambers, and the rate at which the whorls widen, although our specimens appear to be somewhat smaller, having an average length of 6 mm. against 7 to 8 mm. for those from the type locality.

The following description is based on abundant very well preserved specimens from the Moody's Branch at Loc. 12 (Gibson's Landing on the Ouachita River, Caldwell Parish, Louisiana), which show distinctly the surface ornamentation.

Test small, involute, composed of a low dome surrounding the excentrically located proloculum, surrounded by a wide thin flange of nearly uniform thickness composed of a portion of the last whorl which extends beyond the margin of the previous whorl. Length of test up to 6 mm., thickness through the center of the umbonate area about 0.5 to 0.6 mm., thickness of flange from 0.1 to 0.2 mm. Sutures raised, ornamented by closely spaced beads of clear shell material; inter-septal areas slightly depressed, smooth except for an occasional stray bead of clear shell material; on surface of test directly over the proloculum is a large bead of clear shell material from which the sutures radiate, bend forward sharply as they pass over the periphery of the previous whorl, then curve gradually to the periphery, which is bluntly rounded.

Adult test composed of two and one-half to three whorls; only sutures of the last formed whorl visible on the surface; last whorl composed of 21 to 22 chambers.

Sections show the initial chamber to be spherical and about 150 μ in diameter, second chamber reniform, greater diameter about 220 to 250 μ, lesser diameter about 150 μ, the following chambers increase in length rather slowly for the first two whorls, and rapidly in the final whorl.

The number of chambers in each whorl is as follows: First whorl composed of 5 chambers; second whorl composed of 10 to 11 chambers; third whorl composed of 21 to 22 chambers.

Operculina vaughani occurs at Locs. 5, 6, 8–16, inclusive. It has a wide geographical range extending from San Jacinto and Liberty counties, Texas, eastward through Louisiana, Mississippi, to the type locality at U. S. Geol. Survey station 3617, Muckafoonee Creek, Albany, Georgia.

Upper Eocene, Moody's Branch member of the Jackson formation.

Family ORBITOIDIDAE

Genus DISCOCYCLINA Gümbel, 1868

DISCOCYCLINA (DISCOCYCLINA) FLINTENSIS (Cushman)

Plate 32, figures 11, 12

Orthophragmina flintensis CUSHMAN, *1917*, U. S. Geol. Survey, Prof. Paper 108, p. 115, pl. 40, figs. 1–2; *1920*, U. S. Geol. Survey, Prof. Paper 125, p. 44, pl. 9, figs. 3–6; *1921*, U. S. Geol. Survey, Prof. Paper 128, p. 125.

Discocyclina flintensis VAUGHAN, *1926*, Geol. Soc. America, Bull., vol. 35, no. 4, p. 792.

Discocyclina (*Discocyclina*) *flintensis* VAUGHAN, *1928*, Florida Geol. Survey, 19th Ann. Rept., pp. 157, 159, pl. 2, figs. 6–7.

Cushman gave the type locality of *Discocyclina* (*Discocyclina*) *flintensis* (Cushman) as follows:

> Type specimen from U. S. Geol. Survey collection 7117, from Ocala limestone in bluff on west bank of Flint River 1¾ miles above the Georgia Southwestern and Gulf Railway bridge near Oakfield, Lee County, Ga.; upper bed, No. 2 of section; C. W. Cooke, collector.

Specimens of the genus *Discocyclina* are rather rare in the Moody's Branch of Texas, Louisiana, and Mississippi. Thus far we have observed only a few specimens of this genus, these belonging to three species, *Discocyclina flintensis* (Cushman) and two unnamed species which are referred to in this paper as *Discocyclina* sp. A, and *Discocyclina* sp. B.

A single specimen of *Discocyclina flintensis* (Cushman) (Pl. 32, fig. 11) was found by a study of the washed residue from about twelve samples taken at one and one-half foot intervals at locality 12, at Gibson's Landing section of the Moody's Branch, Caldwell Parish, Louisiana. Two specimens of the same species were found in the top part of a core from 4,321–4,331 feet from the Piedmont Oil Company's No. 1 Foster Lumber Company well, San Jacinto County, Texas. The photograph (Pl. 32, fig. 12) is a surface view of the larger specimen which appears to be an adult specimen.

The extreme scarcity of specimens of *Discocyclina flintensis* prevented a study of them by means of thin sections. Their identification was necessarily based solely on surface characteristics.

Test thin, slightly umbonate, thickest in center, surface papillate, papillae from 25 to 50 μ in diameter, largely arranged in concentric rings.

Diameter up to 5 mm.; thickness through center up to about 0.5 mm., ratio of thickness to diameter about 1 to 10.

DISCOCYCLINA sp. A

Plate 32, figures 5–10

Test small, thin, discoid, not umbonate; thins gradually from the center to the periphery which is not covered by lateral chambers; surface of test, with the exception of the peripheral margin, ornamented by rather evenly spaced minute papillae, whose diameters are from 10 to 30 μ, separated by distances from two to three times their diameters. Diameter of test from about 1.4 to 2.25 mm.; thickness about one-seventh to one-tenth of the diameter.

Embryonic apparatus composed of a globular initial chamber having a diameter of about 30 μ, partly embraced by a kidney-shaped second chamber whose dimensions are about 30 to 60 μ.

Equatorial chambers near the center of the test nearly square, about 40 μ wide and from 30 to 50 μ long, at a distance of 1 mm. from the center the chambers have a width of about 40 μ and a length of about 80 μ.

Owing to the lack of sufficient specimens for vertical sections we have little definite information regarding size, shape, and arrangement of the lateral chambers. The examination of the edge of a broken specimen shows from five to six layers of chambers on each side of the equatorial layer near the center of the test; the number of lateral chambers decreasing gradually to the periphery of the test where the equatorial layer is not covered by lateral chambers.

The above partial description is based upon a few specimens from different localities, the specimens for the most part

being poorly preserved. While these specimens belong to a new species of *Discocyclina*, we believe it undesirable to apply a name until sufficient material is available for good type specimens.

A few poorly preserved specimens occur in material from Loc. 13 associated with *Camerina jacksonensis* Gravell and Hanna, n. sp., *Operculina vaughani* Cushman, and *L.* (*Lepidocyclina*) *mortoni* Cushman; a single specimen from Loc. 9, associated with *Camerina jacksonensis* Gravell and Hanna, n. sp.; a single specimen in material from Loc. 14, associated with *Camerina jacksonensis* Gravell and Hanna, n. sp., *Operculina vaughani* and *L.* (*Lepidocyclina*) *mortoni;* and also one from Loc. 15 with the same association of larger foraminifera.

Upper Eocene, Moody's Branch member of the Jackson formation.

DISCOCYCLINA sp. B
Plate 32, figure 13

A single specimen of *Discocyclina* was found in material from Loc. 8, cuttings from 1,733–1,755 feet in the Turnbull and Irwin's No. 1 McShane, Jasper County, Texas. This sample is from approximately 120 feet below the top of the Moody's Branch. Since the sample contained other larger foraminifera from the Moody's Branch, it is believed this specimen is also from the Moody's Branch.

The surface characteristics of this specimen are as follows: Test small, thin, not umbonate, thins gradually from the center to the periphery, which is not covered by lateral chambers, surface of the text appears to be smooth, if there are any papillae present they are extremely minute. The lateral chambers exposed at the periphery of the test are rectangular, about twice as long as wide, the length being about 60 μ, width about 30 μ.

Diameter of specimen (peripheral margin partly broken) 2.5 mm., thickness about 0.3 mm.

This specimen is distinctly different from the three species of *Discocyclina* described from the Jackson of the Gulf Coastal Plain, namely *D. flintensis* (Cushman), *D. floridana* (Cushman) and *D. citrensis* Vaughan, whose occurrence in Georgia and Florida has been discussed by Cushman (5) and Vaughan (16). The most striking difference is the non-papillate character of its surface as contrasted with the distinctly papillate surfaces of the other three species.

This specimen belongs to a new species. We hope to find more specimens of it in order that a sufficient number may be available for sections so that its characteristics may be determined for an adequate description of this species.

Genus LEPIDOCYCLINA Gümbel, 1868

LEPIDOCYCLINA (NEPHROLEPIDINA) FRAGILIS Cushman

Lepidocyclina fragilis CUSHMAN, *1920*, U. S. Geol. Survey, Prof. Paper 125, p. 63, pl. 22, figs. 1–2.

Lepidocyclina (*Nephrolepidina*) *fragilis* VAUGHAN, *1924*, Geol. Soc. America, Bull., vol. 35, no. 4, p. 798, pl. 33, fig. 5; *1933*, Smithsonian Misc. Coll., vol. 89, no. 10, pp. 27–28, pl. 14, figs. 1–4.

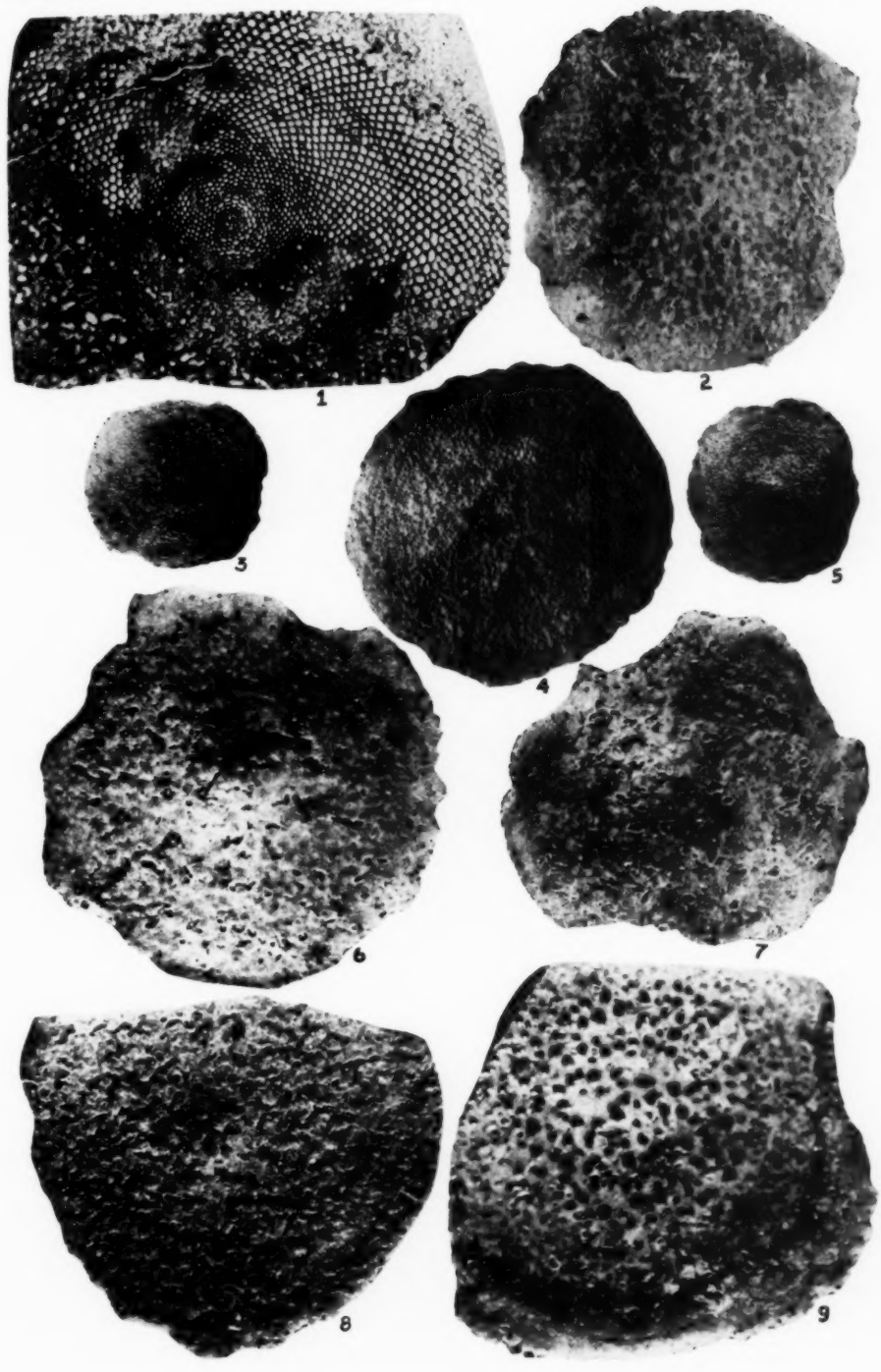
Cushman gave the type locality of *Lepidocyclina fragilis* as follows:

Type specimen from U. S. G. S. station 7194, Ocala limestone, at mouth of cavern about 200 yards southwest of wagon bridge over Chipola River, east of Marianna, Florida; bed 4 of section; C. W. Cooke and W. C. Mansfield, collectors.

Cushman (6, p. 129) reported the following occurrence of *Lepidocyclina fragilis:*

EXPLANATION OF PLATE 30

FIGS. 1–9—*Lepidocyclina* (*Lepidocyclina*) *mortoni* Cushman. 1, Hypotype; thin section of specimen from 22 feet above the base of the Moody's Branch; ×11.9 (Loc. 12). 2, 6–9, Hypotypes; ×11.9 (Loc. 10). 3, Hypotype; specimen from 17 feet above the base of the Moody's Branch; ×2.9 (Loc. 12). 4, Hypotype; from 17 feet above the base of the Moody's Branch; ×2.9 (Loc. 12). 5, Hypotype; opposite side of specimen shown in figure 3; ×2.9 (Loc. 12). (p. 337)



Gravell and Hanna, Eocene Foraminifera

The species (*Operculina ocalana*) occurs in the Moody's calcareous marl member at Moody's Branch, Jackson, Florida (this locality is undoubtedly Jackson, Mississippi), with *O. cookei* and *Lepidocyclina fragilis*. These came to me as loose specimens, apparently from the same horizon.

We have observed no specimens of *Lepidocyclina fragilis* in our samples from the Moody's Branch member of the Jackson Eocene.

LEPIDOCYCLINA (LEPIDOCYCLINA) MORTONI Cushman

Plate 30, figures 1–9; Plate 31, figures 1–11; Plate 32, figures 1–4

Lepidocyclina mortoni CUSHMAN, *1920*, U. S. Geol. Survey, Prof. Paper 125, pp. 70–71, pl. 27, figs. 1–4, pl. 28, figs. 1–3.

Lepidocyclina (*Lepidocyclina*) *mortoni* VAUGHAN, *1924*, Geol. Soc. America, Bull., vol. 35, no. 4, p. 797, pl. 36, figs. 1–2; *1928*, Florida Geol. Survey, 19th Ann. Rept., p. 157. *1929*, Nat. Acad. Sci., Proc., vol. 15, pp. 290, 291, pl. figs. 1, 2.

Cushman's original description was largely based on the microspheric form of *L.* (*Lepidocyclina*) *mortoni*. His figured specimens were all microspheric, although he recognized the presence of the megalospheric form. His description is as follows:

Test flattened, usually somewhat sellaeform, thin; central portion thickest but not umbonate; surface very finely papillate throughout, the papillae most numerous in the central portion. Diameter as much as 20 mm.; thickness slightly more than 1 mm.

The horizontal section shows the chambers of the equatorial band hexagonal in general, but the peripheral portion more commonly a convex curve instead of a sharp angle; embryonic chambers subequal in the megalospheric form, thick walled.

The vertical section shows the chambers of the equatorial band very low, in the center slightly wider than the height but toward the periphery slightly larger and slightly higher than the width, walls thick and at right angles, not showing the convexity of the outer wall so common in most species; lateral chambers seven or eight in a column in the thickened central portion, broad and low, the outer wall usually convex, making the chamber cavity roughly lunate, the walls of the inner chambers nearest the equatorial chambers often much thickened and the chamber cavity reduced to mere slits, the walls often double the thickness of the entire equatorial band at that point, the walls of the outer layers much thinner and the chamber cavities somewhat wider but not porportionately so; pillars very numerous, more or less irregular, often anastomosing, especially toward the surface.

Type specimen from the Jackson formation at U. S. G. S. station 2638, bluff at Montgomery, Grant Parish, La.; T. W. Vaughan, collector, 1894. The species is represented by abundant specimens from the marl at this place. . . . Very similar specimens occur at the following stations: 7161. Ocala limestone, roadside 500 feet east of Jones Field Branch, sec. 35, T. 8 N., R. 3 E., 5 miles southeast of Whatley, Ala.; C. W. Cooke, collector. 7377. Jackson formation, bluff on south side of Suck Creek, Clarke County, Miss., about three-quarters of a mile from the mouth, in the NE. ¼ sec. 3, T. 10 N., R. 7 E., in "*Zeuglodon* bed"; E. N. Lowe and C. W. Cooke, collectors.

Both the microspheric and the megalospheric forms of the test occur. The pillars are peculiar in their anastomosing condition and are shown in the horizontal section (Pl. 27, fig. 3).

Vaughan (15) placed *Lepidocyclina mortoni* Cushman in the genus *Lepidocyclina s. s.* and figured topotypes of the megalospheric form.

A careful study of a large suite of specimens of *Lepidocyclina* (*Lepidocyclina*) *mortoni* from the type locality and from Loc. 12 (Gibson's Landing on the Ouachita River, Caldwell Parish, Louisiana) shows that this species exhibits considerable variation in the general form of the test, particularly in the central area over the embryonic apparatus. Some specimens are umbonate to nonumbonate with symmetrically developed umbos, while others have asymmetrically developed umbos. There is variation in the development of the pillars in different specimens, and a great variation in the size of the embryonic apparatus. These variations are distinctly within the bounds to be expected to occur in an organism which is composed of several hundred chambers. It is possible to arrange these specimens in a complete series, and thus readily see that they grade from extremes of types which at first glance appear to be two or more species. A relatively large number of photographs of *L.* (*Lepidocyclina*) *mortoni* are in-

cluded in the plates in order to show something of this individual variation.

Test of megalospheric specimens of medium size, thin, more or less saddle-shaped, exhibit considerable variation in the shape of the test particularly in the central portion which is occupied by a small but prominent umbo; many specimens have umbos equally or nearly equally developed on both sides of the test (Pl. 32, fig. 4). The development of the umbos grades from nearly symmetrical on both sides of the test to specimens which are distinctly umbonate on one side and broadly concave on the opposite side (Pl. 32, fig. 3).

Surface except the peripheral margin covered with small papillae, whose diameters range from 60 to 180 μ; separated by distances approximately equal to their diameters; papillae largest over the center of the test, and in general decrease in size toward the periphery; individual specimens exhibit considerable variation in the size of the papillae (Pl. 30, figs. 8–9).

Embryonic apparatus composed of two large subequal chambers separated by a straight wall, the dimensions varying greatly in different megalospheric individuals (see Pl. 30). It may measure as little as 0.388 by 0.433 mm. in specimens with the smaller embryonic apparatus to 0.660 by 0.833 mm. in those having larger embryonic apparatus. The two large initial chambers are partly surrounded by several long narrow chambers, some of them are as much as 260 μ long and about 50 μ wide.

Equatorial chambers in horizontal section have curved outer walls and pointed inner ends, radial diameter usually slightly less than the transverse diameter, chambers of somewhat irregular size the average minimum and maximum chambers ranging from those having radial diameters of 90 to 140 μ, and transverse diameters of from 110 to 180 μ. In vertical section the equatorial chambers are about 60 μ high and from 80 to 100 μ long near the embryonic apparatus, at a distance of 4 mm. from the center they are about 150 μ high and 60 μ long; roofs and floors vary greatly in thickness from 15 to as much as 60 μ thick, perforated by minute pores; chamber roofs and floors approximately parallel, walls curved toward the periphery of the test.

Lateral chambers from five to eight layers on each side of the equatorial layer over the center of the test, decreasing in number gradually toward the peripheral portion, which is not covered by lateral chambers; variable in size and height, their general shape is flatly biconvex, length from 60 to 230 μ, height from 10 to 50 μ, roofs and floors perforated by minute pores, the thickness of lateral chamber roofs and floors, like the size of the chamber spaces, is greatly variable, those near the surface to the test being fairly thin and uniform, about 15 μ in thickness, toward the equatorial layer they become irregularly thickened, varying from 15 to 60 μ, the chamber spaces being reduced to mere slits. The lateral chambers in this species are not arranged in regular tiers.

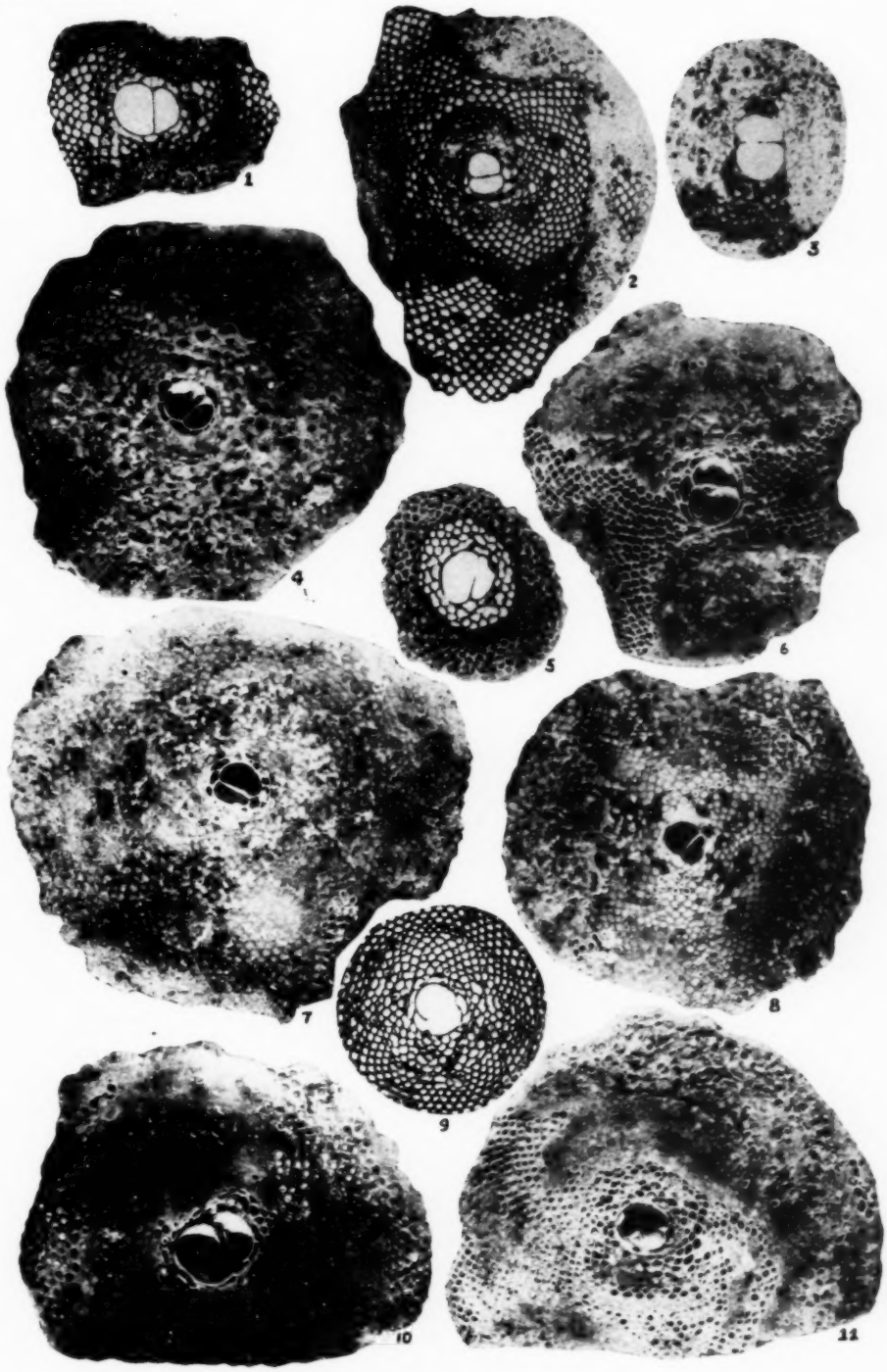
Pillars are formed by the thickened ends of the lateral chambers and are irregular in size and distribution.

Diameter of adult specimens up to 8 mm.; thickness through the center about

EXPLANATION OF PLATE 31

All figures ×11.9

FIGS. 1–11—*Lepidocyclina* (*Lepidocyclina*) *mortoni* Cushman. 1–3, Hypotypes; thin sections (Loc. 10). 4, 7, Hypotypes; half sections (Loc. 10). 5, Hypotype; thin section; from 27 feet above the base of the Moody's Branch (Loc. 12). 6, Hypotype; half section of specimen shown in Plate 30, figure 7 (Loc. 10). 8, Hypotype; half section of specimen shown in Plate 30, figure 2 (Loc. 10). 9, Hypotype; thin section of specimen from 27 feet above the base of the Moody's Branch (Loc. 12). 10, Hypotype; half section of specimen shown in Plate 30, figure 6 (Loc. 10). 11, Hypotype; half section of specimen shown in Plate 30, figure 8. (p. 337)



Gravell and Hanna, Eocene Foraminifera

1 mm; thickness just outside the umbonate area about 0.6 mm., decreasing gradually to about 0.17 mm. at a distance of 4 mm. from the center of the test.

Microspheric form: Test medium sized, thin, somewhat curved, thickest in the center but not umbonate as is the megalospheric form, diameter up to 20 mm.; thickness through the center up to 1.5 mm., usually about 1 mm., decreasing gradually to the periphery; surface of the test covered by papillae, those on central portion of the test are from 60 to 200 μ in diameter, interspaces approximately equal to the diameter of the papillae; papillae decrease in size toward the periphery of the test where they vary from 60 to 100 μ.

Embryonic chambers in horizontal section (Pl. 30, fig. 1) consist of eight or more minute chambers arranged in a coil, this arrangement is characteristic of the microspheric form of all species of *Lepidocyclina*.

Equatorial chambers in horizontal section similar to those of the megalospheric form except those within a radius of 1 mm. of the initial chambers, which are smaller. In vertical section the equatorial chambers at the center of the test are smaller, about 40 μ high and 60 μ long, increasing in size gradually toward the periphery; at a distance of 8 mm. from the center of the test they are 200 μ high and about 100 μ long; roof and floor of the equatorial layer is thick, having a thickness of about 90 μ near the center but decreasing to about 30 μ at the periphery.

As many as fourteen layers of lateral chambers over each side of the equatorial layer in the central portion of the test, this number decreasing gradually to the periphery where the equatorial layer is not covered by lateral chambers. The lateral chambers are similar to those of the megalospheric form in that they are low, broad, of irregular size, not arranged in regular tiers, and in the great thickening of the chamber roofs and floors of those chambers near the equatorial layer. Pillars formed by the thickening of the overlapping ends of the lateral chambers, cone-shaped and of rather irregular development and distribution, slightly larger than those of the megalospheric specimens.

Fairly abundant at Loc. 10 (Cushman's type locality of *L. mortoni*) associated with *Camerina moodybranchensis* Gravell and Hanna, n. sp., and *Operculina vaughani* Cushman; abundant at Loc. 12 associated with *Operculina vaughani* Cushman and a single specimen of *Discocyclina flintensis* (Cushman); Loc. 13, associated with *Camerina jacksonensis* Gravell and Hanna, n. sp., *Operculina vaughani* Cushman and *Discocyclina* sp. A.; present at Locs. 9 and 11. The above localities are all in Louisiana. In Mississippi *L.* (*Lepidocyclina*) *mortoni* occurs at Locs. 13, 14, 15, and 17. In Texas it occurs at Loc. 8.

Upper Eocene, Moody's Branch member of the Jackson formation.

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EXPLANATION OF PLATE 32

All figures ×11.9

FIGS. 1–4—*Lepidocyclina* (*Lepidocyclina*) *mortoni* Cushman. 1, 3, Hypotypes; thin sections of specimens from 17 feet above the base of the Moody's Branch (Loc. 12). 2, 4, Hypotype; thin sections (Loc. 10). (p. 337)

5–10—*Discocyclina* sp. A. 5, Loc. 13. 6, Loc. 14. 7, Partial thin section of specimen shown in figure 6 (Loc. 14). 8, Specimen from a core from 4,776? feet (Loc. 9). 9, Loc. 15. 10, Opposite side of specimen shown in figure 9 (Loc. 15). (p. 335)

11, 12—*Discocyclina flintensis* (Cushman). 11, Hypotype; from 22 feet above the base of the Moody's Branch (Loc. 12). 12, Hypotype; specimen from the top of a core from 4,321–4,331 feet (Loc. 5). (p. 335)

13—*Discocyclina* sp. B. From cuttings from 1,733–1,755 feet (Loc. 8). This sample of cuttings is from approximately 120 feet below the Moody's Branch. Since the sample contained other foraminifera from the Moody's Branch, it is believed this specimen is also from the Moody's Branch. (p. 336)

Gravell and Hanna, Eocene Foraminifera

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SOME MID-PENNSYLVANIAN INVERTEBRATES FROM KANSAS AND OKLAHOMA: II. STROMATOPOROIDEA, ANTHOZOA, AND GASTROPODA

NORMAN D. NEWELL
Lawrence, Kansas

ABSTRACT

One typical stromatoporoid, two corals, and eight gastropods are described from the Lansing group. *Parallelopora*, *Dibunophyllum*, and *Tropidocyclus* are recognized for the first time in the American Pennsylvanian. Of the species described in this paper nine are new.

This is the second paper of a series dealing mainly with new forms discovered in a general study of the invertebrate faunas of the upper part of the Missouri series (Moore) in eastern Kansas and northern Oklahoma.

The types described herein and in the first paper are preserved in the geological museum at the University of Kansas, and at Peabody Museum, Yale University.

SYSTEMATIC DESCRIPTIONS

STROMATOPOROIDEA

Genus PARALLELOPORA Bargatzky, 1881

PARALLELOPORA MIRA Newell, n. sp.
Plate 34, figures 6–10

The test is massive, hemispherical or botryoidal, and encrusting, in some cases, perhaps invariably, originating at a small surface of attachment. If there is a basal epitheca it has not been observed. Weathered fragments show a very fine structure of radiating thread-like elements. Concentric ridges on weathered surfaces suggest periodic growth. These ridges, spaced 1 to 3 mm., correspond to layers that are relatively resistant to weathering but thin sections do not show well defined transverse elements corresponding to the surficial ridges.

Transverse sections show closely spaced irregular cylindrical cavities or tubes, which lack a definite wall. These tubes are irregularly circular, whereas others appear exceedingly irregular by what seems to be a lateral union of two or more of the cavities. The individual tubes range in diameter between about 100 and 250 microns but compound ones produced by the lateral union of two or more tubes may reach 1 mm. in the greatest dimension as seen in transverse section. The tubes are spaced irregularly up to about one-half mm. The spaces between the tubes contain spicular elements of two sorts. The dominant type of spicules are straight acicular monaxons having a diameter of the order of 10 microns and a length up to 250 microns. These are vertically directed, parallel to the irregular radiating tubes. Very much smaller but otherwise similar spicules are disposed essentially transverse to the larger ones. The spicules are clearly circular in transverse section.

Longitudinal sections show that the regions between the radiating tubes are

literally made up of the closely crowded spicules set in pigmented granular calcite, whereas the calcite of the tube spaces is clear and colorless. The individual spicules apparently have undergone alteration because they do not behave optically like single calcite crystals. The sides of the tubes are exceedingly ill defined and in detail attain extremes of irregularity, although the trend is a linear one, directly upward. At short but very irregular intervals complete or partial partitions obstruct the cavities. The material composing these obstructions cannot be differentiated from remainder of the structure. In many instances adjoining tubular cavities are connected by coarse rounded, or subcylindrical openings through the sides.

Discussion.—The distinctions which *Parallelopora mira* presents from typical *Parallelopora* might be considered differences of degree and consequently any hesitation in assigning the new form to that genus may be unjustified. Of greater significance is the fact that the genus *Parallelopora* is still poorly understood, unless there have been recent studies unknown to me based on authentic material. According to Nicholson (8, p. 95),[1] who has restudied and figured some of Bargatzky's types,

> the radial and horizontal elements of the skeleton (are) so amalgamated as to give rise to a continuously reticulated framework, traversed by vertical tabulate zooidal tubes. The coarse, reticulated skeleton fiber is traversed by irregular vertical tubuli, or by minute dark-colored vertical rods, which are united at intervals by horizontal bars. Astrorhizae are present.

Nicholson was not certain whether or not there were minute tubuli or "rods" in the regions between the zooidal cavities. There can be no question as to the nature of the spicular system in the Kansas species because the preservation is so good that the individual spicules may be viewed in three dimensions through the surrounding calcite.

Bargatzsky (1) was confident that the "rod-like" bodies were interstitial tubes occupying all of the spaces between the larger tubes. It is quite likely that in a general way the structure of the Kansas species falls well within the limits of *Parallelopora*.

The genus *Parallelopora* is a characteristic stromatoporoid. The true stromatoporoids were compared by Twitchell(12) to sponges. He stated that the so-called tabulae of the stromatoporoid do not completely obstruct the tubes but serve as pillars. Periodic growth so characteristic of the stromatoporoids he demonstrated to be not incompatible with growth in certain modern sponges. True spicules were demonstrated in certain of the stromatoporoids. There is but little question that the organization of *P. mira* recalls the structure of sponges in the irregular and indefinite form of the tubes. On the other hand it is so nearly like some stromatoporoids that it seems probable that it belongs to a group that has been so classified. It is beside the point to attempt an analysis of the relationship of sponges and stromatoporoids at this place, but it seems that the Kansas form incorporates features of both groups.

Although *Parallelopora* was described from the German Devonian, Yabe and Sugiyama (13) have described a stromatoporoid from the Permian of the province of Mino in Japan, which they named *Stromatopora* (*Parallelopora*) *minoensis*. In general structure the Japanese form resembles the present species but seemingly lacks the spicular structure, although the spicules might have been destroyed during fossilization.

Distribution.—About two scores of worn fragments ranging in size up to two inches or so across were found at the base of the Vilas shale at a railroad quarry near the center of the SW. $\frac{1}{4}$ sec. 11, T. 20 S., R. 19 E., Anderson County, Kansas. A few very small and poorly preserved fragments were collected at the

[1] Numbers refer to bibliography at the end of paper.

same horizon at a large quarry on the highway two miles north of Garnett, Kansas. The types are in the geological museum at the University of Kansas. Supplementary types are placed in Peabody Museum, Yale University.

ANTHOZOA

Genus ZAPHRENTIS Rafinesque

ZAPHRENTIS WANNENSIS
Newell, n. sp.
Plate 33, figures 4–9

? *Hapsophyllum* ? *sp.* GIRTY, *1915*, U. S. Geol. Survey, Bull. 544, Wewoka formation, Oklahoma, p. 28, pl. 2, fig. 10.

The corallum is small, cylindro-conical and either straight or slightly curved, with the concave side including the cardinal septum. The epitheca is thin, with faint growth lines and well marked septal sulci. The calyx in complete individuals is probably shallow and is marked by a well defined cardinal fossula which is continuous with a circular central depression. Indistinct alar and counter fossulae may be observed in some specimens. There is no columella. The calyx is floored by a tabula of distinctive shape. The outer area of the tabula is raised into a horseshoe-shaped fold or elevation which is open at the fossula and like the floor of the fossula is depressed slightly toward the cardinal region. The peripheral part of the tabula is depressed into a deep groove where it joins the theca at an acute angle. The edges of a few coarse dissipiments are seen near the periphery in weathered specimens. The primary septa, about 24 to 28 in number, extend to the edge of the central depression. Rudimentary secondary septa occur in large specimens but are generally absent in average individuals.

Axial sections show closely spaced tabulae of the same shape as that flooring the calyx. Where the tabulae join the septa the latter extend slightly farther inward along the upper surface of the tabulae than at the under surface. The crest and outer slopes of the horseshoe-shaped fold of the tabulae are occupied by a few broad, coarse dissepiments having the same general aspect as the tabulae. The tabulae extend completely across between the thecal walls although axial sections in the plane of a septum give the impression that the tabulae do not extend to the theca.

Measurements of Zaphrentis wannensis

Holotype	Paratype 1	Paratype 2
Primary septa 28	24	26
Secondary septa 27	None	None
Length 41.5 mm.	25 mm.	30 mm.
Diameter 16 mm.	13.6 mm.	15 mm.

Discussion.—Only a single species of *Zaphrentis* has been described from the American Pennsylvanian, namely *Z. gibsoni* White from Indiana. It may be distinguished from *Z. wannensis* by its more numerous septa, greater size, and flaring sides. The new species is probably the same as that described by Girty from the Wewoka formation as *Hapsophyllum* ? sp. The present form cannot be ascribed to *Hapsiphyllum* Simpson, because in that genus there is

> an inner area bounded by a sub-vertical wall of horse-shoe shape, open on the side of the septal fovea. Two of the larger septa connect with this wall in such a manner as to be apparently a continuation of it, and form a very distinct pyriform septal fovea (10).

Distribution.—The type specimens were found in shales of Lansing age at Wann, Oklahoma. These specimens are now at the University of Kansas and Peabody Museum, Yale University.

Genus DIBUNOPHYLLUM
Thomson and Nicholson, 1876

DIBUNOPHYLLUM VALERIAE
Newell, n. sp.
Plate 33, figures 1–3

The corallum is simple and conical, with a thin epitheca marked by encircling growth lines and gathered at intervals into roughened annuli of growth. The corallum is slightly arched and in some specimens the tip is strongly curved. Septal sulci are obscure or lacking. The calyx is deep, exhibiting a cen-

tral prominence surmounted by a laterally compressed ridge corresponding to a median columellar lamella. The convex area surrounding the end of the columellar axis is modified in unweathered specimens only by blister-like tabellae. These tabellae are inclined against the bladelike axial plate of the columella in such a way that a central boss or prominence is formed occupying almost completely the floor of the calyx. Except for the axial plate, vertical lamellae do not reach the floor of the calyx in large specimens, having ceased to grow before complete maturity.

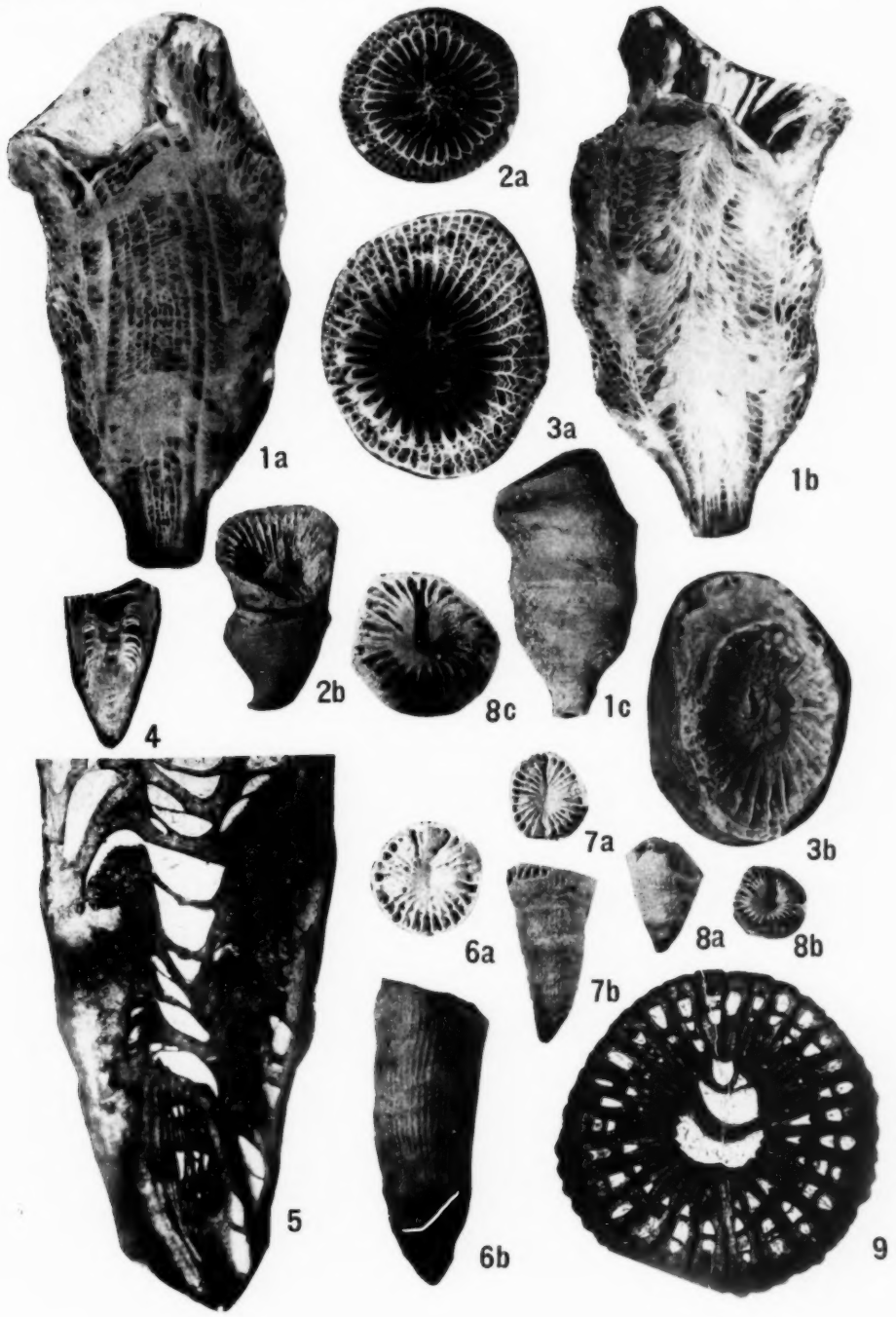
Axial sections show a three-fold division of the internal structures. A dense peripheral zone is characterized by rather closely spaced interseptal dissepiments which are inclined steeply against the walls of the corallum. The outer zone is separated from an axial zone by a relatively less dense intermediate area. The two inner zones are characterized by small curved platelets or tabellae which are inclined inwardly against the axis. In centered axial sections the tabellae appear to have the convex surfaces uppermost. The tabellae of the intermediate zone are inclined at a low angle and are fairly open and loosely arranged. This condition changes toward the axis where they are more steeply inclined against the axial plate of the columella and consequently are closely crowded, producing a relatively dense axial zone.

Transverse sections show that the septa are well developed and of two orders. The primary septa, about 34 in number, are moderately long, reaching a third of the distance across the corallum. They are lamellar and strong at the inner half, but toward the periphery become thin and irregular. The confused relationship of the outer ends of the septa with the dissepiments produces in some instances an impression of branching in the peripheral area. The secondary septa are thin, but distinct, and commonly do not extend quite as far as the inner margin of the peripheral vesicular zone. The intermediate zone appears open textured in this section because of the low angle at which the tabellae intersect the plane of the section. The inner zone including the columellar structures appears dense because of the high inclination of the tabellae to the plane of section and because of their crowding. A very thin, irregular axial plate extends from an obscure fossula on the convex side of the corallum to the ends of the opposite primary septa. Eight or more irregular thin lamellae radiate outward from the sides of the axial plate extending in some cases to the ends of the much thicker primary septa. The lateral lamellae are distinguished from the axial plate only by the fact that

EXPLANATION OF PLATE 33

FIGS. 1–3—*Dibunophyllum valeriae* Newell, n. sp. 1*a-c*, A paratype from the Eudora shale (Stanton formation) in northeastern Woodson County, Kansas. 1*a*, A longitudinal section a little to one side of the central axis, which shows well the cessation in upward growth of the vertical tabellae at a mature stage, ×2. 2*a–b*, A paratype from the Eudora shale in northwest Allen County, Kansas; 2*a*, polished transverse section just below bottom of calyx, ×2; 3*a–b*, the holotype from the Eudora shale in northeast Woodson County; 3*a*, transverse section cut just under the bottom of the calyx, ×2; 3*b*, view of calyx showing the blister-like tabellae in the mature stage, unlike typical *Dibunophyllum* in which the ends of vertical lamellae are visible at the central boss of the calyx. (p. 343)

4–9—*Zaphrentis wannensis* Newell, n. sp. Holotype and paratypes from Lansing shale at Wann, Oklahoma. 4, Paratype, centered longitudinal section of corallum through alar region, showing arched tabulae, ×1. 5, Paratype, centered longitudinal section of apical part of corallum through cardinal fossula, cardinal side on the right, ×4. 6 *a–b*, Holotype, the largest observed specimen; 6*a*, view of calyx, ×1; 6*b*, side view, ×1. 7*a–b*, Paratype, ×1; 7*a*, view of calyx; 7*b*, side views. 8*a–c*, Paratype; 8*a*, side view, ×1; 8*b*, view of calyx, ×1; 8*c*, same, ×2, showing horseshoe-shaped tabulae with cardinal fossula whose floor slopes steeply toward the periphery. 9, Paratype, transverse section, just under calyx, ×4. (p. 343)



Newell, Pennsylvanian invertebrates

no two lateral plates originate at the same point on the axial lamella but have the appearance of having been derived from the axial plate, consequently they are approximately half as long in transverse sections as the axial lamella. Subordinate lamellae extend inward a short distance from many of the primary septa.

The highly inclined tabellae as seen in transverse sections occur in a single series between each pair of vertical lamellae, and produce a vague concentric pattern about the center suggesting to a slight extent the structure of a spider-web. In this section some of the tabellae have the convex surface facing inward, some appear straight, and most of them have the convex side facing outward. In the characteristic species of *Dibunophyllum* from the British Lower Carboniferous the tabellae in transverse sections are concave outward from the center but as in the present species the tabellae, shown in centered axial sections that avoid the lamellae but include the axial plate, are convex upward. If the tabellae in the British forms were simple blister-like structures then they would appear curved in all sections. The convex outline would face upward in the axial sections and outward in transverse sections, rather than inward. Obviously the tabellae in the British forms are not cyst-like platelets, but may be considered as trough-like plates contained between two lamellae with the axis of the troughs arched, so that axial views of the coral show the up-arched axis of the troughs with the arching in the plane of the lamellae, and transverse sections intersect the lamellae at right angles and show the trough-like depression of each tabella.

The Kansas species differs from the characteristic forms of *Dibunophyllum* in that most of the tabellae in transverse sections are either straight or convex outward, and only a few have a trough-like form as viewed between lamellae. The tabellae that appear convex in both axial and transverse sections are to be thought of as convex plates of blister-like form confined generally between two diverging lamellae. Since the lamellae were of necessity deposited before the tabellae that surrounded them it may be supposed that the form of the tabellae is a function of the height of the lamellae above the floor of the calyx at the time the tabellae were formed. Prominent lamellar ridges on the floor of the calyx would permit folds of the polyp to descend into the interlamellar spaces. In such a case the tabellae would be concave viewed from above although the central prominence of the calyx would cause the tabellae to be convex in the radial direction. Any tendency toward loss of the lamellar ridges of the calyx would involve a necessity for the local lifting of the basal disc in the polyp before a tabella could be deposited, precisely in the same way that the dissepiments are formed, and the resultant tabellae would be blister-like in appearance.

Such a situation occurs in the present species. At an advanced stage all of the lamellae excepting the axial one ceased to grow and the floor of the calyx in adults is covered by blister-like tabellae. It may be supposed that if there had been a progressive loss of the radiating lamellar ridges in the central area of the calyx during ontogeny that tangential sections including some of the lamellae would show a progressive change from tabellae that are concave above in the juvenile parts of the corallum to straight and then convex tabellae in the mature stages. This sequence is not shown, however, in the material at hand, but no concave tabellae occur above the upper extremities of the vertical lamellae.

The dimensions of three specimens from a single horizon and three separate localities are given below:

Measurements of Dibunophyllum valeriae

Holotype	Paratype 1	Paratype 2
Length 25 mm.	25.8 mm.	37 mm.
Max. diam. 20 mm.	17.5 mm.	18 mm.
No. primary septa 34	34	34
Depth of calyx 5.5 mm.	7± mm.	6 mm.

Discussion.—There are several points of divergence between *Dibunophyllum valeriae* and characteristic British Lower Carboniferous species. The present form lacks the lamellar ridges in the floor of the calyx, although these probably occur in juveniles. The secondary septa are relatively longer and more distinct than in the Lower Carboniferous forms. Furthermore, the tabellae in the Kansas species are characteristically convex as viewed in transverse or tangential sections although this is not an invariable rule. The broad axial blade of the columella unites this species with *Dibunophyllum* rather than any of a host of similar genera. It seems that the points of departure from typical *Dibunophyllum* are not so numerous as the resemblances. If several similar species are found in the Pennsylvanian some justification may be found for setting these forms aside from those of the Lower Carboniferous. No other Pennsylvanian species appears yet to have been assigned to *Dibunophyllum*. Apparently the present form might equally well be referred to *Arachnolasma* Grabau (3) from the Lower Carboniferous of Kweichou, China. If that is the case then *Arachnolasma* is a synonym of *Dibunophyllum*. Possibly the present species has been classed by some paleontologists as *Axophyllum rude* W. and St. J. As originally defined *A. rude* exhibits contorted growth, and is commonly attached along the greater part of one side. It was said to have numerous stolons extending root-like from the epitheca.

The new species is dedicated to my wife, Valerie, in acknowledgment of her assistance in making this study.

Distribution.—The three known specimens of *D. valeriae* come from the Eudora shale in the vicinity of Neosho River. The holotype and some paratypes were found at the northeast corner of sec. 27, T. 24 S., R. 17 E. The types are in the geological museum at the University of Kansas.

GASTROPODA

Genus ORESTES Girty, 1911

ORESTES PAGODA Newell, n. sp.

Plate 36, figures 4, 4*a*

The single specimen at hand referred to this species is moderate-sized, measuring 14 mm. in height and 12 mm. in greatest width. The spire is quite high with a fairly uniform angle of about 62 degrees and having about 8 volutions. The whorl section is sharply angular, having a flattened lateral surface which is nearly parallel to the shell axis and is bounded above and below by a moderately high angular keel. The lower keel is less prominent than the upper one and is wholly visible only in the last volution, being partly concealed at the inner volutions by the inner edge of succeeding whorls. The upper shoulder of each volution is slightly concave. It is nearly perpendicular to the axis in the early volutions but becomes depressed at the periphery in the later whorls forming an angle of about 50 degrees with the axis. The flattened lateral surface meets the shoulder above at an angle of about 123 degrees and joins a flat basal surface abruptly at about 107 degrees. A slit band occupies about the middle one-fourth or one-third of the lateral surface; it is about 0.8 mm. broad in the last whorl. The band is bounded above and below by a relatively coarse carina.

The surface of the whorls is cancellated by coarse revolving and transverse lirae and there is a tendency for the formation of small papilli at the intersection of the lirae. There are 6 or 7 revolving lirae on the upper surface of the outer whorls between each pair of which are interposed 7 or more very fine obscure revolving lirae. The transverse lirae are parallel to the growth lines and are evidently produced by periodic bundling of the growth lines. They are not precisely transverse to the whorl, but are inclined slightly backward exhibiting little or no curvature. Transverse lirae continue from the upper surface of the whorls

across the lateral area, swinging symmetrically backward above and below across the band. The ornamentation of the basal surface is like that of the upper surface, consisting of intersecting revolving and transverse lirae.

Discussion.—There is no described species in the American Pennsylvanian with which this is likely to be confounded. It may be distinguished readily by the high spire, numerous volutions, and ornate appearance.

Distribution.—The single specimen from which the species is known was collected from Lansing shale at Wann, Oklahoma, just above a thin flaggy limestone exposed in the hills at that place.

Genus PHANEROTREMA Fischer

PHANEROTREMA ? WANNENSE Newell, n. sp.

Plate 36, figures 2*a–c*

The shell is turbinate with a moderately high spire the sides of which appear nearly straight or slightly convex in profile. The apical angle is characteristic of the species, ranging between 75 and 87 degrees in some scores of specimens. In profile the upper surface of the whorls is very faintly convex and the submarginal areas are markedly concave near the marginal slit-band. The upper surface declines about 40 to 50 degrees from the axis of coiling in the later whorls, and somewhat less in the early volutions. The band is broad and distinctly concave and forms the crest of the keel-like periphery.

The under surface of the last whorl is concave next to the slit-band but below this is strongly convex across the base into the umbilicus. The upper surface of the whorls is ornamented with from 6 to about 12 revolving lirae. Commonly the spacing of the lirae is somewhat irregular and in some specimens they are crowded and finer toward the outer margin of the whorls. Growth lines are bundled at short, regular intervals to produce slightly coarser lines, these being particularly coarse near the inner margin of the whorls. Where these fascicles cross the revolving lirae small acute nodes are formed, those nearest the periphery being obscure and slightly elongate along the revolving lirae, whereas those toward the inner margin are more distinct and are obliquely transverse along the growth varices. The two or three rows of nodes next to the inner margin of the apical whorls are relatively coarse but in the later whorls these become less well differentiated.

The slit-band is bounded by distinct lirae or carinae and commonly it contains an obscure low ridge or carina at the center occupying a fourth or more of the width of the band. This ridge is absent, however, in many of the specimens. The slit was deep, as determined by the growth lines on certain specimens, extending backward a third of a volution from the point where the inner lip joins the penultimate whorl.

The concave submarginal part of the base (or side) commonly bears from 2 to 4 revolving lirae ornamented with nodes like ones on the upper surface. The convex umbilical part of the base has up to 10 or more of the revolving lirae upon which nodes are superimposed at the intersections with the coarse growth varices. The umbilicus is partly closed by a thickened inner lip and by the inner margin of a thin but distinct inductura which covers the base of each successive whorl up to the last volution. In full-sized individuals there are about 7 volutions. In the early volutions the submarginal part of the shell is covered by the succeeding whorls, only the slit-band and upper surface being visible, but in the last 3 volutions a considerable part of the submarginal area is visible so that in these whorls there is a distinct keel.

The following specimens were selected with the view of indicating the range of variation in proportions.

Measurements of Phanerotrema? wannense

	Holotype	Paratype 1	Paratype 2
Apical angle	79°	87°	75°
Volutions	7	7.5	7

Spire height	18 mm.	18 mm.	19 mm.
Breadth	18 mm.	18 mm.	15 mm.
Width of slit	0.9 mm.	0.9 mm.	0.9 mm.

Discussion.—This form closely resembles *Phanerotrema? grayvillense* and it undoubtedly has been confused with that species. The original description and figures of *P.? grayvillense* (N. and P.) indicate a low spired form such as that described by Girty (2, p. 149) from the Wewoka formation of Oklahoma, in which there is scarcely any of the submarginal surface visible in any but the last whorl. From *P. ? grayvillense* the present form may be readily distinguished by its larger size, higher spire, and less prominent nodes at the inner margin of the whorls. The most obvious distinction has already been indicated, that in the later whorls of *P. ? wannense* a considerable part of the submarginal surface appears above each succeeding whorl. From *P. ? marcouianum* (Geinitz) it may be distinguished by its larger size and distinctly lower spire. The species *P.? welleri* Newell is a similar form but it is distinctly larger, has a higher spire, and a broader submarginal area exposed in the inner whorls. Furthermore *P.? welleri* has a narrower and higher keel and consequently there is a distinct concave area on the upper surface adjoining the keel. In *P.? wannense* the keel is not particularly narrow and the upper surface of the whorls is relatively flat. Furthermore the number of revolving lirae on the upper surface of the whorls in *P.? welleri* is rarely less than 11 or 12 and the lirae are commonly fine, but in *P.? wannense* the lirae on the upper surface are relatively coarse and in many specimens number less than 8 or 10.

Distribution.—This species characterizes shales of Lansing age above a thin, flaggy limestone in the hills at Wann, Oklahoma, and at the same horizon 2 miles west of Wann. The types are placed in the geological museum at the University of Kansas, and duplicates are kept at Peabody Museum, Yale University.

PHANEROTREMA? WELLERI
Newell, n. sp.
Plate 36, figures 3*a–g*

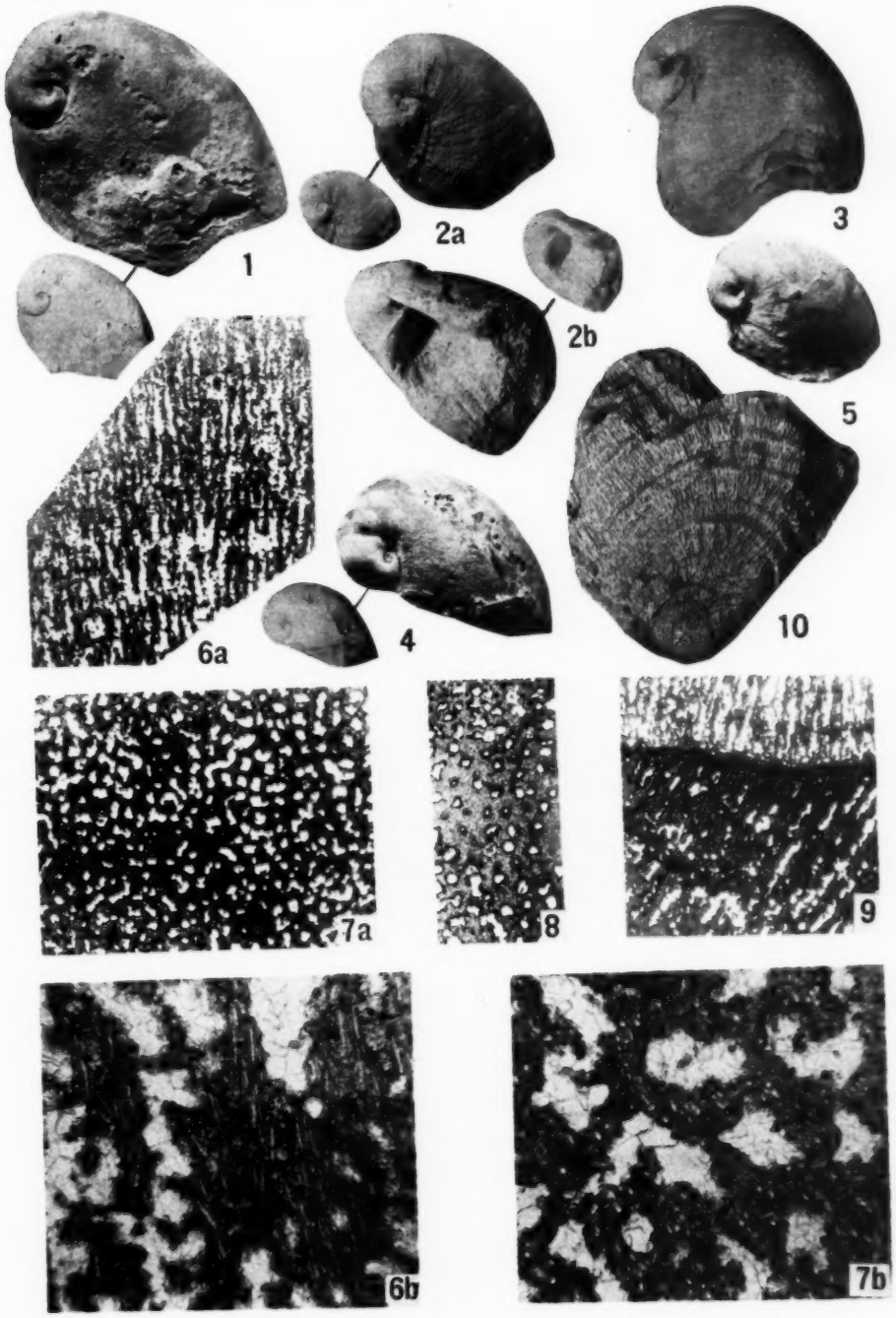
?*Worthenia tabulata* PLUMMER and MOORE, *1921*, Texas Univ., Bull. 2132, pl. 19, fig. 25.

The shell is turbinate, high spired, and large, one gerontic paratype with about 9½ whorls having a height of 30 mm. and a breadth through the aperture of 27 mm. In profile the spire has slightly concave sides. The apical angle is characteristically rather small, ranging between about 75 and 85 degrees. The upper surface of the whorls is flattened or slightly convex except near the band where it is faintly concave. The upper surface in mature whorls is declined from the axis of coiling at an angle of 45 to 60 degrees. The periphery is occupied by a prominent, narrow keel which bears the relatively broad slit-band. The band is either flattened or slightly convex and is bounded on either side by a narrow carina. As seen in profile the band is not quite parallel to the axis but inclined slightly toward the apex.

EXPLANATION OF PLATE 34

FIGS. 1–5—*Helictostylus girtyi* Newell. 1, Paratype, side view, ×2. 2*a–b*, Holotype, ×2; 2*a*, side view; 2*b*, aperatural view, showing spiral fold. 3–5, Paratypes, side view, ×2. All specimens from the Olathe limestone (Stanton formation) at Fredonia, Kansas. (p. 353)

6–10—*Parallelopora mira* Newell, n. sp. All specimens from the basal Vilas shale, north and northwest of Garnett, Kansas. 6*a–b*, Paratype; 6*a*, radial section, ×8; 6*b*, same, showing system of spicules, ×45. 7*a–b*, Paratype; 7*a*, transverse or tangential section, ×8; 7*b*, same, showing the spicules (white dots) in cross section, ×45. 8, Tangential section of another paratype, ×8. 9, Radial section of a paratype showing a new growth on an old, dense growth, ×8. 10, The holotype, showing the concentric or periodic growth visible in weathered specimens, ×1. (p. 341)



Newell, Pennsylvanian invertebrates

The exceptional elevation of the slit band results in a concavity both above and below it. The sides below the keel are flat in a broad area nearly parallel to the axis. At the lower margin of this flattened area the surface bends abruptly inward toward the axis and curves directly into the umbicilus.

The upper surface of the whorls is ornamented with 10 to 14 revolving lirae which are crossed at regular intervals by fine transverse lirae produced by a periodic bundling of the obliquely arched growth lines. Small acute nodes are formed at the intersections of the lirae. In most specimens the lirae become smaller and more closely spaced toward the periphery, finally becoming obsolete at the base of the peripheral keel. On the juvenile whorls only the innermost lirae are visible, the outer ones being added during the development of the shell. There is little or no differentiation of nodes on the upper surface of the outer whorls but relatively coarse and obliquely transverse nodes occur at the inner margin of juvenile whorls while other nodes are very faint or lacking. The relative coarseness of the inner nodes in the juvenile whorls is due to the circumstance that the inner lirae and the inner part of the growth ribs are relatively coarser in the younger whorls than in other parts of the shell. The flattened area below the keel has, in mature whorls, from 6 to 8 revolving lirae which bear nodes at the points of intersection with growth ribs. These lirae are comparable in coarseness with the lirae at the inner part of the upper surface of the whorls. The convex base has about 15 nodose lirae, relatively coarse ones alternating with moderately fine ones. Apparently the finer lirae are introduced by intercalation during the shell growth. The inner lip of the aperture is thickened and partly recurved about the axis, but the umbilicus is open. A thin inductura is present.

This description is taken from about two scores of specimens from the Eudora shale in Montgomery County, Kansas. The species is dedicated to Dr. J. Marvin Weller. The following measurements indicate the nature of variation.

Measurements of Phanerotrema? welleri

	Holotype	Paratype 1	Paratype 2
Apical angle	73°	85°	70°
Volutions	8.5	9±	9.5
Spire height	21 mm.	22 mm.	30± mm.
Breadth	17 mm.	21 mm.	26 mm.
Width of slit	0.6 mm.	0.8 mm.	0.7 mm.

Discussion.—In spite of the close resemblance to *Worthenia tabulata* the lack of nodes on the slit-band eliminates the present form from the genus *Worthenia*. A similar form is *Phanerotrema? marcouianum* (Geinitz). Geinitz's species is much smaller than *P.? welleri*, n. sp. and more particularly has at all stages a much less prominent peripheral keel.

J. Brookes Knight has demonstrated to me that the Devonian genotype of *Phanerotrema* does not agree very well with the Pennsylvanian species generally referred to *Phanerotrema*; consequently the present species has been referred only provisionally to that genus.

Distribution.—This species characterizes the Eudora shale (Stanton formation) in a small area in southern Montgomery County, Kansas. The types were collected from a road-cut at the northwest part of section 6, T. 34 S., R. 15 E. The species has also been found in the upper part of the Stranger formation below the brick plant at Peru, Kansas. The types are kept at the geological museum of the University of Kansas, and at Peabody Museum, Yale University.

Genus TROPIDOCYCLUS Koninck, 1883

TROPIDOCYCLUS CORDIFORMIS Newell, n. sp.

Plate 36, figures 1*a–d*

The shell is of moderate size, discoidal, and planospiral, with about three regularly increasing volutions in adults having a length of 11 mm. The whorls are subcordate in section. The subacute periphery bears a relatively broad rounded

ridge which might be considered the slit-band. On either side of the ridge the profile is faintly concave, rounding into gibbous lateral areas and thence curving abruptly inward to the steep-walled umbilicus. The umbilical slope is divided into two concave areas by a relatively prominent sharp ridge located outward from the margin of the impressed zone one-third of the width of the umbilical slope. About one-half of each of the inner whorls is embraced by the succeeding volution and the margins of the impressed areas are elevated into narrow, sharp ridges. The surface is ornamented by transverse lirae which apparently are produced by a periodic bundling of growth lines. At the surface inside the umbilical ridge fine lirae curve symmetrically backward. At the umbilical ridge these fine lirae apparently become fascicled to produce very much larger and fewer ribs which swing forward in an arc across the outer concave area of the umbilical slope of each whorl. At the umbilical shoulder new lirae are introduced by intercalation, commonly between alternate lirae or in some cases appearing as seldom as after every seventh lira. The lirae are particularly coarse across the inner half of the lateral areas and in this space they are nearly straight and transverse to the whorls. Near the middle of the lateral surfaces the lirae become less prominent, increase in number slightly by intercalation of a few new ones, and swing broadly backward into a deep peripheral sinus. A thin inductura covers the peripheral surface of the inner whorls. There is no evidence of an umbilical callus at any stage. The species is based upon 12 specimens from a single locality. The following measurements indicate the amount of variation.

Measurements of Tropidocyclus cordiformis

	Holotype	Paratype 1	Paratype 2
Length	13.3 mm.	11.2 mm.	5.8 mm.
Breadth of aperture	9 mm.	9 mm.	3.8 mm.
Height of aperture	6.8 mm.	6.8 mm.	3.8 mm.
Breadth of slit-band	2.3 mm.	2.2 mm.	1.0 mm.

Discussion.—This unique little gastropod is apparently the first species of *Tropidocyclus* to be recognized in the American Pennsylvanian.

Distribution.—The only known specimens of the species were found in Lansing shale at Wann, Oklahoma, and 2 miles west of Wann.

Genus Trepospira Ulrich

Trepospira discoidalis Newell, n. sp.

Plate 35, figures 8–11

Mature examples of this species are large, commonly attaining a diameter of 40 to 45 mm. At a diameter of 45 mm. the somewhat gerontic holotype has about $6\frac{1}{4}$ volutions. It is seldom that the apical volutions can be counted in ma-

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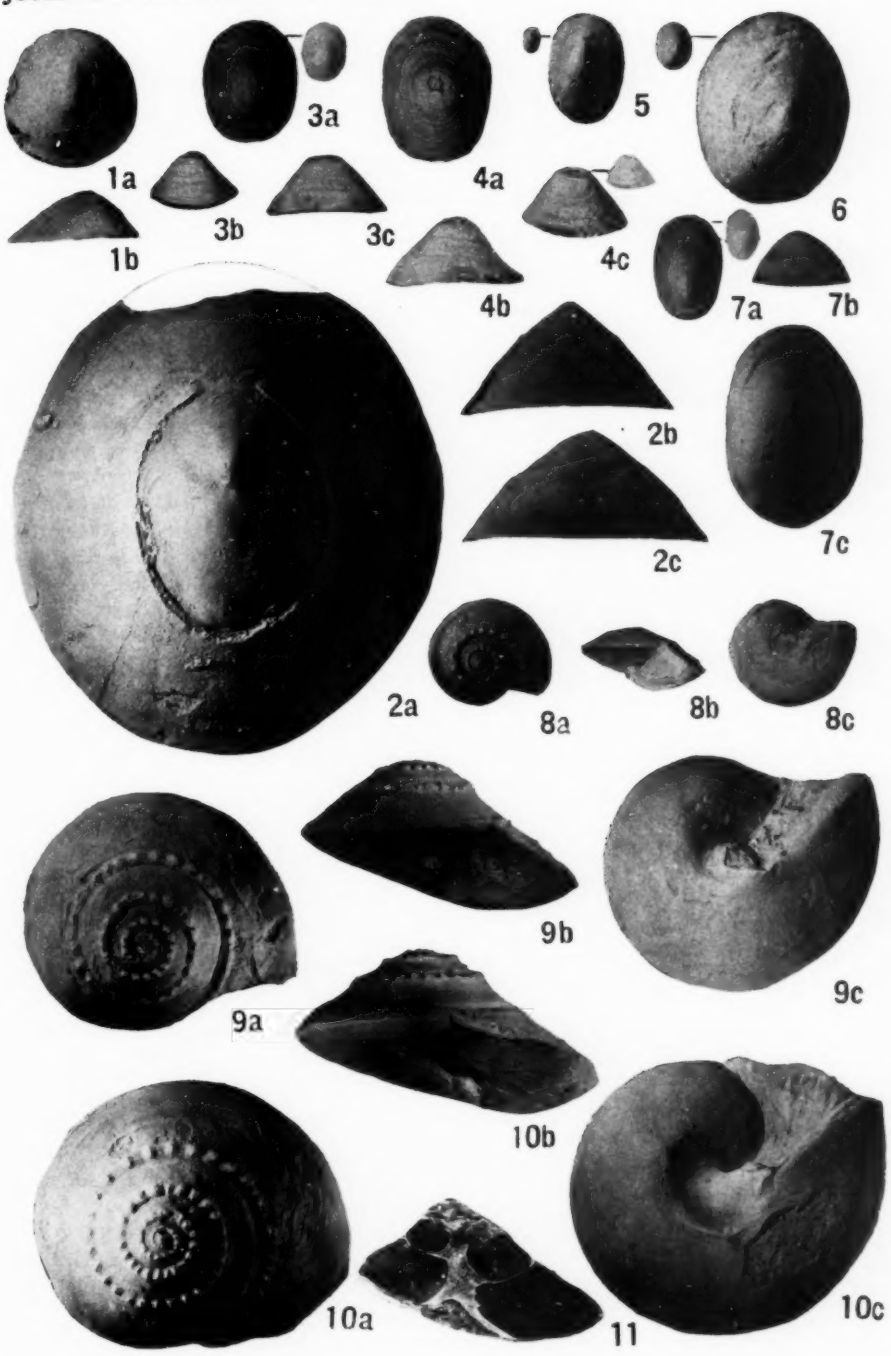
Explanation of Plate 35

Figs. 1*a*–2*c*—*Lepetopsis parrishi* Gurley. 1*a*–*b*, A hypotype, ×1; this specimen differs from typical *parrishi* in having the apex closer to the front margin. 2*a*–*c*, One of Gurley's types from Kansas City (Winterset limestone?), designated here as the lectotype, 2*a*, ×2, 2*b*–*c*, ×1. (p. 351)

3*a*–7*c*—*Lepetopsis peregrina* Newell, n. sp. All specimens from the Olathe limestone (Stanton) at Fredonia, Kansas. 3*a*–*c*, The holotype, ×2. 4*a*–*c*, A paratype, showing a marked concavity of lateral profile toward the broad end of the shell, ×2. 5, Paratype, external squeeze, showing the strongly curved nucleus, ×5. 6, External squeeze of a paratype, showing a vestigial nucleus, ×5. 7*a*–*c*, Paratype, showing short muscle scar; 7*a*–*b*, ×2, 7*c*, ×4. (p. 352)

8*a*–11—*Trepospira discoidalis* Newell, n. sp. All specimens from Eudora shale (Stanton) near Tyro, Montgomery County, Kansas. All figures ×1. 8*a*–*c*, Juvenile paratype, apical, side, and basal views. 9*a*–*c*, Typical adult, paratype; apical, side, and basal views. 10*a*–*c*, Holotype, a gerontic specimen, apical, side, and basal views. 11, Paratype, sectioned to show the solid axis and form of whorl section. (p. 350)



Newell, Pennsylvanian invertebrates

ture specimens and the above number is an estimate obtained with the aid of juvenile paratypes. The shell is moderately depressed and the apical angle is large, ranging between about 96 and 113 degrees, commonly with an angle of about 105 degrees. Next to the spiral seam there is a row of small, subhemispherical nodes, with acute, transverse crests. There are 25 to 40 of these in the sixth volution. The slit-band is supermarginal and is bounded outwardly by the sharp periphery and inwardly by a small but distinct lira. In large sized specimens the slit-band ranges in width between 2 and 2.5 mm. It joins the upper surface of the whorls at a decidedly obtuse angle. The upper surface of the outer volutions is slightly convex next to the slit-band flattening inward and thence becoming gently concave over the inner two-thirds of the upper surface. The lower surface of the whorls has a low and regular convexity and the curvature does not increase perceptibly at the margins.

The umbilicus is closed by a callus which is centrally depressed in such a manner as to resemble a spiral trough. The growth lines indicate a deeply reentrant slit in the aperture but the depth of the slit cannot clearly be determined. Except for the growth lines and nodes referred to above the shell surface is smooth.

Discussion.—This shell clearly belongs to the group of *Trepospira depressa* of authors. Two names are in current usage for Pennsylvanian Trepospiras, all others being generally considered absolute or subjective synonyms. These are *Trepospira depressa* (Cox) and *T. sphaerulata* (Conrad). Miller (6) suppressed *Pleurotomaria depressa* Cox as a homonym of *Pleurotomaria depressa* Phillips, and he renamed Cox's species *P. kentuckiensis*. Specimens at hand from the Kendrick shale of Floyd County, Kentucky, apparently representing authentic *Trepospira kentuckiensis*, exhibit several marked differences from the new form. The present species has a much greater size, lower convexity of the upper surface of the whorls, a higher spire with flattened slopes, and a particularly acute keel. Furthermore the Kentucky specimens exhibit very little of the trough-like concavity of the callus shown so well in *T. discoidalis*. In the apical angle and acute periphery the present form resembles *T. illinoisensis* (Worthen). Worthen's species may be distinguished by its paucity of nodes and its small size. It probably occurs at a lower horizon than *T. discoidalis*. Girty (2, p. 153) described a *Trepospira* from the Wewoka formation and a very similar form occurs in the Cisco group of Texas (9). These forms are relatively smaller than *T. discoidalis* and have a rounded keel like *T. sphaerulata* rather than a sharp keel like *T. discoidalis*. There is a tendency in *T. discoidalis* for the upper surface of the whorls to be concave near the inner margin whereas the Oklahoma form lacks this feature. The Oklahoma and Texas forms alluded to are generally known under the name *Trepospira depressa* but they do not agree very well with Cox's species.

Distribution.—The types come from the Eudora shale (Stanton formation) in southern Montgomery County and specimens of it were found just above the Avant limestone at Avant, Oklahoma, and below the Avant in sec. 16, T. 22 N., R. 12 E.

Genus LEPETOPSIS Whitfield, 1882

LEPETOPSIS PARRISHI Gurley

Plate 35, figures 1–2

Lepetopsis parrishi GURLEY, *1884*, New Carboniferous fossils, Bull. 2, p. 7 [Private publication].

The original description of this patelliform gastropod was not accompanied by illustrations and the species has not been since described. The two syntypes of *Lepetopsis parrishi* were kindly lent from Walker Museum by Professor Carey Croneis and it has seemed desir-

able to redescribe them. Each of the types is an internal mold showing clearly the well defined muscle scar.

The shell is asymmetrically conical with a flat and regularly elliptical base. The height is about half the length and the shell is about one-eighth longer than it is wide. The apex is slightly nearer one end than the other and the arrangement of the muscle scar suggests that the short end is anterior. As seen in profile the anterior slope is faintly concave for a third of the length forward from the apex thence becoming moderately convex down to the concave border. Since the specimens are internal molds the surface is gently concave near the margin, thus reflecting the thinning of the margin of the shell proper. The rear slope is convex from the apex to the marginal concave rim. Just behind the apex the mold shows a small bulge, the convexity of which is subordinate only to the apex. Except for the narrow concave border the sides are broadly convex in profile.

The shell material is lacking and the details of surface ornamentation are unknown. A large number of small, closely spaced radial ribs can be seen with difficulty on the molds, and these possibly reflect a similar but much more distinct surface ornamentation. A prominent feature of the mold is the reverse of a horseshoe-shaped muscle scar with the open ends directed toward the short end of the shell. The scar consists of a relatively broad, elevated band, the inner edge of which is raised abruptly above the apical area of the mold. The outer margin of the scar is surrounded by a narrow and faintly depressed area. The apex rises from a point about a third of the length of the muscle scar back from the open ends. Whereas the scar crosses the anterior slope less than a third of the way down from the apex, it crosses the posterior slope about midway between the margin and apex. Just behind the apex and directed anteriorly there occurs on either side of the mold an obscure and narrow groove which terminates at the inner margin of the muscle scars.

Measurements of the two types are given below. These bear the catalogue number 6330 of Walker Museum, Chicago University. The larger specimen is a particularly fine one and it is designated here as the lectotype.

Measurements of Lepetopsis parrishi

	Lectotype	Paratype
Length	33 mm.	27 mm.
Breadth	30 mm.	23 mm.
Height	15 mm.	10 mm.
Breadth of muscle scar	15 mm.	11 mm.
Length of muscle scar	19 mm.	14 mm.
Width of scar band	2 mm.	1+mm.

Discussion.—Gurley's types came from Kansas City, Missouri. They occur in a drab oolitic matrix in which there are many iron-stained fragments of gastropods and pelecypods. It appears probable that the types were found in the upper part of the Winterset limestone. There are two horizons at Kansas City famous for their molluscan faunas. These are the upper part of the Westerville ("Drum") and the upper part of the Winterset. Both horizons contain oolite, but the oolitic limestone of the Westerville is generally white and that of the Winterset is generally drab or dark-gray.

Distribution.—Two fragmentary specimens referred to this species were found in the exotic fauna of the Olathe limestone at Fredonia, Kansas.

LEPETOPSIS PEREGRINA
Newell, n. sp.

Plate 35, figures 3–7

The shell is relatively small, patelliform, and elongate, with a subelliptical base which is slightly arched from front to back. In mature specimens the apex is nearly central and bluntly rounded, but in small, immature specimens there is coiled tip or nucleus extended toward one end of the shell. Apparently this nucleus is lost by breakage or by abra-

sion before a mature stage is reached. The lateral margins are subparallel and the sides are somewhat flattened. In some specimens the end nearest the apex has a distinctly concave profile, but in several moderate sized individuals both ends are convex. The shell is not quite symmetrical from a side view in these specimens but commonly the slope which in other individuals is concave is more steeply inclined than the slope at the opposite end.

There is no trace of radial ornamentation in several specimens retaining the shell, but there is a distinct concentric ornamentation consisting of somewhat irregularly bunched growth varices. Since one specimen exhibits a muscle scar across the steeper slope at one end of the shell this end should probably be considered as posterior. By circumstance of the tendency toward concavity at the posterior end and more rapid growth at the anterior margin the growth varices in adult shells are depressed toward the rear so that they pass obliquely backward across the sides of the shell. The anterior end of the shell is less steep in profile than the posterior slope and is distinctly convex, with the convexity increasing slightly next to the margin. Some shells are slightly narrower at the front than at the rear whereas others have lateral margins that are practically parallel.

A remnant of the nucleus occurs in some of the small juveniles. It appears at the apex as a small triangular nub, somewhat wedge-shaped at the anterior end and rounding less abruptly at the posterior end. Probably the nucleus was coiled at the earliest stage but in the 15 specimens at hand it was either broken away and the fracture healed or it was lost by abrasion. There is only one specimen that shows a trace of the muscle scar. The scar is a U-shaped narrow groove which crosses the posterior end about halfway between the apex and the periphery. The ends of the groove extend forward less than a third of the length of the shell and then become invisible. The following measurements indicate the change in dimensions during the stages of growth.

Measurements of Lepetopsis peregrina

	Paratype 1	Holotype	Paratype 2
Length	3.5 mm.	8.0 mm.	10.0 mm.
Breadth	2.5 mm.	6.0 mm.	7.5 mm.
Convexity	3.7 mm.	3.7 mm.	4.0 mm.
Apex	subanterior	central	central

Discussion. — Perhaps this species should not be referred to *Lepetopsis* Whitfield. The elongate form of the shell and especially the short muscle scar and arched base would seem to exclude it from that genus as generally interpreted. On the other hand the bases for discriminating generic groups in Paleozoic shells like the present one are not well understood and it appears desirable to class the new species with *Lepetopsis* for the present, rather than to propose a new generic name.

Distribution.—The new species is relatively common in the Olathe ("Stoner") limestone member of the Stanton formation at Fredonia, Kansas. The types, which come from this locality, are placed in the geological museum at the University of Kansas, and in Peobody Museum, Yale University.

Genus HELICTOSTYLUS Knight, 1934

HELICTOSTYLUS GIRTYI Newell

Plate 34, figure 1–5

Helictostylus girtyi NEWELL, *1934*, in Knight, Jour. Paleontology, vol. 8, p. 165, pl. 25, figs. 2*a–f*.

In general form the shell at hand recalls *Platyceras* or the shells commonly classified as *Strophostylus*. The largest of the thirty specimens measures 25 mm. in length as measured through the outer margin of the aperture. The shell consists of two to two and one-half tightly coiled, rapidly expanding volutions of which the last constitutes by far the greater part of the shell. The apical part of the shell is depressed so that there is

scarcely a distinguishable spire. At a shell length of 4 mm. and one and one-half volutions the form is distinctly platyceratoid. At this stage there occurs a slight constriction followed by abrupt expansion of the aperture so that the nucleus of adult shells is distinctly set off from the later part of the shell. The inner lip of the aperture at mature stages is thickened to form a sort of columella with a flattened margin. The growth lines are sinuous and irregular apparently at all growth stages suggesting that the organism was attached throughout much of its life. The whorl section and aperture in large specimens is more or less strongly depressed in a direction parallel to the axis so that the form is elliptical. Commonly old specimens display a deep and broad sinus at the outer margin of the lip. The margin of the lip in such specimens is generally quite irregular. A thin inductura covers the surface of the inner lip. The dimensions of three characteristic specimens are given below:

Measurements of Helictostylus girtyi

	Holotype	Paratype 1	Paratype 2
Length	7.7 mm.	16.2 mm.	25.0 mm.
Height*	4.3 mm.	13.7 mm.	14.7 mm.
Height of Aperture	5.4 mm.	10.9 mm.	13.6 mm.

* Parallel to the axis.

The specific name is given in honor of that distinguished student of Carboniferous faunas, Dr. George H. Girty.

Discussion.—Knight (4) has shown that *Strophostylus* has been confused with forms quite unlike the genotype species. The genus should be restricted to relatively high-spired phaneromphalous forms like *S. elegans* (Hall) having distinct transverse lirae. For forms like the species described above having no umbilicus, but with a completely coiled shell bearing a revolving fold on the columella, he has proposed the name *Helictostylus*. The genera *Orthonychia* and *Platyceras* are distinguished from *Helictostylus* by the uncoiled body whorls(5).

Apparently *Helictostylus girtyi* is the only member of the genus thus far discovered in the American Pennsylvanian.

Distribution.—The species is common in the Olathe ("Stoner") limestone of the Stanton formation at Fredonia, Kansas. It is unknown elsewhere. The types are at the University of Kansas, and Peobody Museum, Yale University.

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6. Miller, S. A., *North American geology and paleontology*, p. 421, 1889.

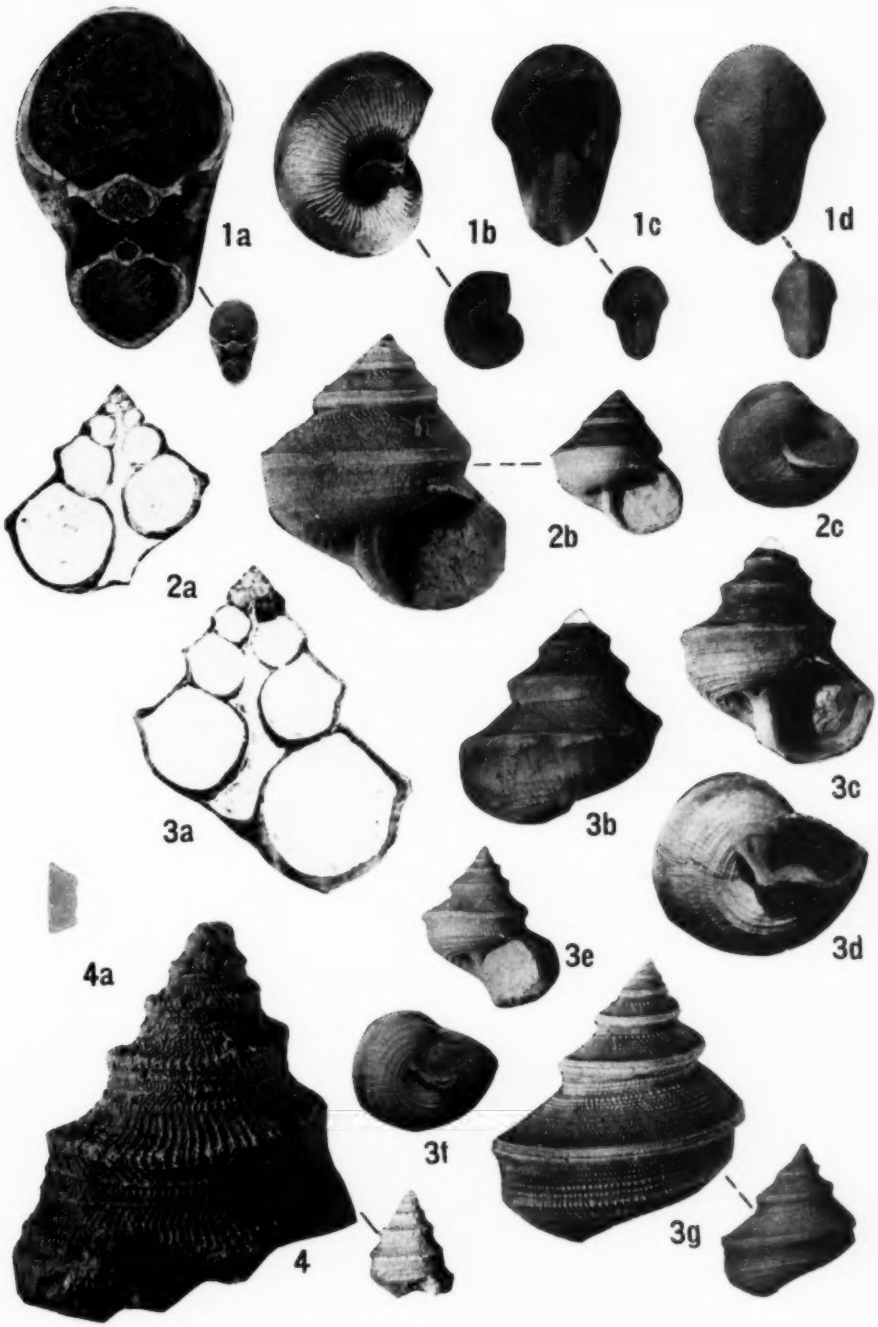
Explanation of Plate 36

Figs. 1*a–d*—*Tropidocyclus cordiformis* Newell, n. sp. Specimens from Lansing shales near Wann, Washington County, Oklahoma. 1*a*, paratype, polished section, ×4; 1*b–d*, holotype, ×2. (p. 349)

2*a–c*—*Phanerotrema ? wannense* Newell, n. sp. Specimens from Lansing shales near Wann, Oklahoma. 2*a*, Paratype, sectioned to show hollow axis and form of whorls, ×2; 2*b–c*, holotype; 2*b*, apertural view, showing well the characteristic form of the spire, ×2; 2*c*, basal view, showing a distinct inductura and the recurved inner lip which partly obscures the open umbilicus, ×1. (p. 347)

3*a–g*—*Phanerotrema ? welleri* Newell, n. sp. Specimens from the Eudora shale (Stanton formation) near Tyro, Montgomery County, Kansas. 3*a*, Paratype, section showing the shape of whorl section and open umbilicus, ×2; 3*b–d*, a relatively large paratype, ×1; 3*e–g*, the holotype; 3*e*, apertural view, ×1; 3*f*, basal view, ×1; 3*g*, side view, ×2. (p. 348)

4–4*a*—*Orestes pagoda* Newell, n. sp. Specimen from Lansing shale near Wann, Oklahoma. 4, The holotype, side view, ×4; 4*a*, same, profile of body whorl, ×1. (p. 346)



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PALEONTOLOGICAL NOTES

OSTRACODA OF THE GENUS *ARGILLOECIA* FROM THE CRETACEOUS OF TEXAS

C. I. ALEXANDER
Magnolia Petroleum Company, Shreveport, Louisiana

In the summer of 1933 the writer received a grant-in-aid from the National Research Council, for the collecting of fossil Ostracoda. Most of the collections were made from strata of Tertiary age, but new collections were also made from several Cretaceous outcrops which previous experience has shown to be unusually fossiliferous, in the hope that improved technique in the preparation of the samples for study would reveal small and fragile shells previously destroyed or lost. These collections have produced numerous minute, thin-shelled Ostracoda, some of which are referable to genera not previously known in strata of Cretaceous age, and some of which appear to be entirely new. It is my intention to present a series of short papers describing each of these genera and their Cretaceous representatives.

In a recent number of this Journal, I recorded the occurrence of two species of the genus *Argilloecia* Sars, 1865, in the Midway formation of Texas, and presented a detailed description of the generic characters.[1] Two species have now been recognized in the Upper Cretaceous formations in Texas. One of these is identified with the Midway species, *A. subcylindrica* Alexander. The other is described as new, and constitutes the earliest recorded occurrence of a definitely identified member of this genus.

[1] Alexander, C. I., Ostracoda of the Midway (Eocene) of Texas: *Jour. Paleontology*, vol. 8, p. 213, 1934.

Suborder PODOCOPA Sars
Family CYPRIDAE Baird, 1846

Genus ARGILLOECIA Sars, 1865.

ARGILLOECIA SUBCYLINDRICA Alexander

Argilloecia subcylindrica ALEXANDER, *1934* Jour. Paleontology, vol. 8, p. 314, pl. 32, fig. 17, pl. 35, fig. 16.

This species, described from glauconitic clay of the basal, Littig, member of the Midway, has been recognized in collections from several outcrops of the Navarro formation. The specimens from the Navarro average slightly larger in size than those from the basal Midway, but are exactly similar in every other respect.

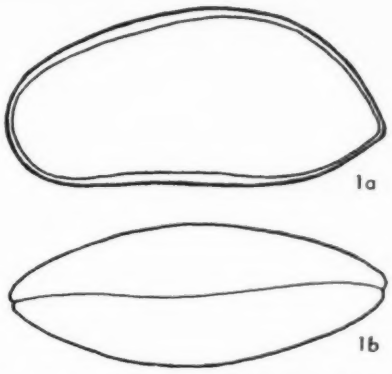
ARGILLOECIA TAYLORENSIS
Alexander, n. sp.
Text figures 1 (1*a*, *b*) *a*, *b*

Carapace minute, in side view elongate highest at about middle. Height equal to slightly less than one-half of length. Dorsal margin rather strongly and evenly arched. Ventral margin nearly straight in anterior half, slightly convex in posterior half, and curving upward gently toward posterior end. Anterior low, evenly rounded. Posterior end subacute. Right valve overlaps left around entire periphery with strongest overlap along anterior half of dorsal and along middle of ventral margin. Carapace in dorsal view lanceolate, widest at middle; ends similar, acute. Surface of valves smooth.

Length of holotype 0.46 mm., height 0.22 mm., width 0.17 mm.

A. taylorensis is similar in general appearance to the Midway species *A. faba*[2] Alexander, but differs in a number of important characters, the most obvious being the more evenly rounded anterior end, the slight, but pronounced, upward swing of the ventral margin posteriorly, and the less produced and somewhat more obtuse posterior end.

A. taylorensis has been recognized in a few outcrops of upper Taylor clays. Holotype collected from an exposure on the right bank of Onion Creek near the bridge at Moore and Berry's Crossing, 8.5 miles in a straight line southeast of the State Capitol building in Austin, Texas. This locality is described as Station No. 226-T-8, in *Texas Univ., Bull.* 3101, p. 121, fig. 12, 1931.



FIGS. 1*a*, *b*—*Argilloecia taylorensis* Alexander n. sp. *a*, Lateral view, left side; *b*, dorsal view. ×110.

[2] Alexander, C. I., Ostracoda of the Midway (Eocene) of Texas, *Jour. Paleontology*, vol. 8, p. 213, pl. 32, fig. 16, pl. 35, figs. 12, 14, 1934.

AMMONIUM CHLORIDE SUBLIMATE APPARATUS

CHALMER L. COOPER
Walker Museum, University of Chicago

The methods of producing ammonium chloride sublimate usually recommended either produce coatings that are too coarse-grained or necessitate apparatus too cumbersome to use advantegeously in a photographic laboratory on the same table with a microscope and camera. The method described by Ulrich and Bassler[1] requires two bottles, one containing hydrochloric acid and another ammonium hydroxide. It is unsatisfactory because of the excessive moisture present, which results in a grain-size too large for use in microphotography. The method used by Branson and Mehl[2] employs sal ammoniac in a small bore tube which is heated over a gas flame. This method produces a fine grain, but the objections to an open flame on the work table are obvious. These objections led to experimentation with an electrically heated tube.

A Pyrex glass tube, one inch in diameter, was blown to the shape shown in Figure 1*a*. It was found that a simple opening of fairly large diameter on the exit end of the tube was preferred to a smaller nozzle-shaped opening, for with the latter type of orifice there is a deposition of the sublimate in the cool end of the nozzle, which soon clogs. The glass tube is covered with one thickness of light-weight asbestos paper and then wound with a heating coil similar to those used in electric heaters and toasters. The coil is stretched to about 42 inches in length, which will give about

[1] Ulrich, E. O. and Bassler, R. S., *U. S. Nat. Mus., Proc.*, vol. 68, art. 12, pp. 3–4, fig. 1, 1926.

[2] Branson, E. B. and Mehl, M. G., *Missouri Univ. Studies*, vol. 8, no. 1, p. 17, 1933.

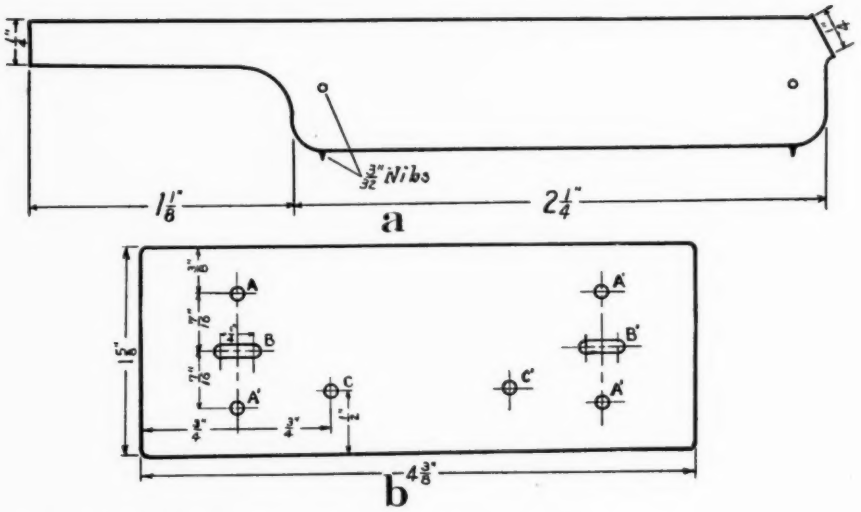


FIG. 1.—*a*, Side view of glass tube.
b, Diagram of "transite" board, showing location of holes to be drilled.

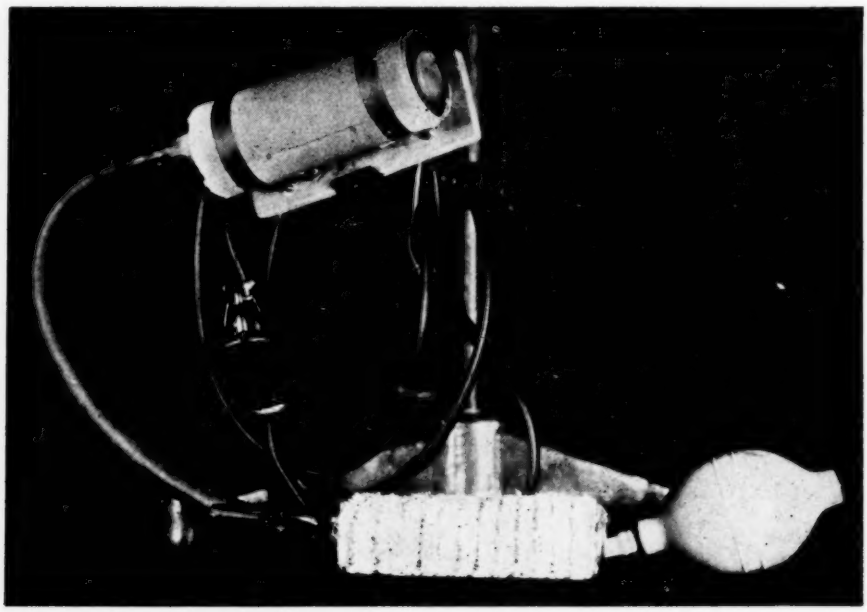


FIG. 2.—Assembly of complete apparatus. An extra tube without covering of asbestos is shown in lower foreground.

12 or 13 turns about the tube. The three small nibs on each end of the tube (one on each side and the third on the bottom) prevent the coil from slipping. The space between the windings of the coil is then filled with one-strand asbestos packing, as shown in the lower part of Figure 2. The tube and coil are then wrapped with three plies of asbestos paper and secured with brass strips, long enough to provide holes for bolts to fasten the tube to a piece of "transite" (asbestos) board. This board should be drilled as shown in Figure *b*. Holes at *A* and *A'* are for the bolts which fasten the brass strips, passed through the holes *B*, *B'* and bent back. Holes *C* and *C'* are for the binding posts for the ends of the heating coil and to which the two wires of the lamp cord are attached. An ordinary laboratory clamp is used to attach the apparatus to the ring stand. About one foot of rubber hose is used between the end of the tube and an atomizer bulb. Figure 2 shows the complete apparatus set up for use. A snap switch, placed about a foot from the end of the lamp cord attached to the coil, is an added convenience.

About one tablespoonful of sal ammoniac is distributed along the bottom of the tube. This may be heated in a little over one minute after the current has been turned on. As soon as the sublimate issues from the end of the tube the current should be turned off. A gentle even pressure of the bulb is then sufficient to expel a stream of sublimate for coating the surfaces to be photographed. As soon as the sublimation stops, only a few seconds of reheating are required to start it again. Care should be taken not to overheat the tube, which will soften and warp under excessive heat. If the tube is inclined about 15° the hose end will not heat sufficiently to burn the hose and the opposite end will be hot enough to retard the deposition of ammonium chloride in the opening. For coating large objects, the apparatus may be held by the "transite" back and the stream of sublimate directed where desired.

Almost any degree of whiteness may be secured by this method, since a very fine grain is produced. A magnification of about 100 diameters is required to detect any grain size.

The total cost of materials is about $1.50 and, with the exception of the tube and bulb, can be purchased at any store selling hardware supplies. The bulb can be purchased at a drug store, and the tube can be made by any competent glass blower.

LIST OF MATERIALS

1 1-inch Pyrex glass tube, 6 inches long.
1 piece asbestos paper, light weight, 4 inches by 20 inches.
1 heating coil, 500 watts, 110 volts.
1 piece asbestos packing, single strand, 42 inches long.
2 brass strips, 3/8 inch by 8 inches long.
1 piece "transite" asbestos ¼ inch by 1 5/8 inches by 4 3/8 inches.
6 stove bolts, ½ inch long.
2 stove bolts, ¼ inch long.
1 rubber hose, ¼ inch by 1 foot long.
1 atomizer bulb.
1 glass tube, ¼ inch by 1½ inches long, for connecting bulb hose to rubber hose.
5 feet lamp cord.
1 snap switch.
1 plug connection.

A NEGLECTED METHOD FOR MAKING THIN SECTIONS OF FOSSILS[1]

K. J. MURATA
U. S. Geological Survey, Washington, D. C.

Commonly it happens that some of the most interesting species in collections of fossil plants or animals are rare ones represented by only a few specimens. This has been the case

with certain petrifactions of stems, roots and petioles with their internal cellular structures preserved, studied in the paleobotanical laboratory of the U. S. Geological Survey during the fall of 1934. For example, it became necessary to make a series of thin sections of the petiole of a new plant, a solitary piece 8 millimeters in diameter and 18 millimeters long. To make the cuts with the ordinary band saw or copper disk was undesirable, owing to the comparatively large waste of material in the kerfs, and the limitation thus placed on the number of sections that could be made.

The collodion-pull method, commonly used in such a case because of its economy of material, was likewise unsatisfactory, the carbonaceous matter of the tissues being almost entirely replaced by calcium phosphate. Further, while excellent collodion pulls have been obtained from many types of petrifactions in the paleobotanical laboratory, actual thin sections are generally preferred for the study of the finest details. Critical portions of specimens are often lost during the etching and drying processes.

To make the maximum number of actual thin sections from a minimum amount of material the ancient technique of sawing with a thin wire, fed with a fine abrasive, has been revived. Although first tried out as a dubious experiment, this has worked very well, and the gratifying results justify a brief discussion of this simple method, particularly in view of the fact that its possibilities do not seem to be generally known.

The materials necessary may be purchased at a very small cost (75¢ to $1.00) at any hardware or variety store and at an electrical shop. They include: (1) a small vise to hold the specimen; (2) a spool of 34-gauge copper wire (enamel-coated), diameter 0.16 mm.; (3) some fine carborundum, powder size (600); and (4) a piece of plate glass about 5 by 8 inches, together with some glass slides, balsam, and a cup in which the water-carborundum mixture may be kept.

A smooth surface in the desired plane of section is first ground on the specimen with the fine powder on the plate glass. This face is then mounted on a slide with balsam in the ordinary way. The excess balsam is carefully trimmed off by means of a razor blade or a similar instrument. The specimen is then clamped by the free end in the vise with the mounted face vertical.

A convenient length of the copper wire, reeled off the spool, is laid across the top of the specimen at the position of the desired cut. A few drops of carborundum-water mixture are added, and with the wire held taut in the hands, the cutting is commenced by pulling the wire back and forth across the block with a slight tension. The addition of a small chip or two of soap to the carborundum mixture when it is made up greatly increases cutting efficiency, but care must be used not to add too much soap.

As the groove develops, the carborundum mixture is added from time to time with a dropper or a small rod. The wire naturally wears down rapidly, but this is offset by reeling more from the spool, and always sawing with fresh lengths. Breaks occur frequently enough to render jigsaw frames or bow arrangements unhandy. But with the wire gripped with the fingers, and with judicious feeding of carborundum, cuts through calcareous and phosphatic specimens 2 centimeters in diameter can be made in fifteen to twenty minutes.

A fairly straight cut results. The thickness of the slice remaining on the slide is ordinarily a half a millimeter or less. The width of the kerf is of the order of a quarter of a millimeter. The cut slice is ground down to the desired thinness with the carborundum mixture on the piece of plate glass. Twelve cross sections have been prepared from 10 millimeters of the petiole mentioned at the beginning of this note. Of course, after each cut the face must be smoothed by grinding. Silicified specimens have not been tried as yet, but it is obvious that the technique can be adapted to such materials. Also the method is most effective with pieces less than 3 centimeters in diameter. An automatic carborundum feed would be a great advantage if much cutting is to be done.

Serial sections cut close together have

[1] Published with the permission of the Director, U. S. Geological Survey. Manuscript received February 2, 1935

made it possible to trace the development of many features along the length of the fossil. Small protuberances and traces on the sides of the stem or petiole have been nipped off with the wire and sectioned.

An interesting adaptation of this wire method has been worked out by a brachiopod specialist at the U. S. National Museum. Instead of grinding away the beaks of his shells in order to get a view of the internal structures, he has started cutting them off with the wire. The very narrow kerf makes it possible for him to glue the beaks back upon the rarer forms, after examining the interior, and there is very little difference in the external appearance before and after the cutting has been done.

The wire method thus makes possible the thorough study of small and rare fossils. It enables certain features such as leaf scars to be removed for sectioning without much marring of the original piece. The excellent slides that can be prepared by its means, the very low cost of the necessary equipment, and the simplicity and adaptability of the method commend it to the attention of paleontologists and students of natural history in general.

SOCIETY RECORDS AND ACTIVITIES

SUMMARIZED MINUTES OF THE NINTH ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The ninth annual meeting of the Society of Economic Paleontologists and Mineralogists was held in the Aviation Room of the Allis Hotel, Wichita, Kansas, Friday afternoon, March 22nd, and Saturday morning, March 23rd, 1933. The meeting was held in conjunction with the regular annual convention of the American Association of Petroleum Geologists, also in session at the Allis Hotel, March 21st, 22nd, 23rd, 1935.

The activities of the Society began with a luncheon at the Innes Tea Room which about 60 paleontologists attended. Jerry Upp served most effectively as toastmaster and the group listened to some timely remarks from the invited speaker, Mr. William B. Heroy, retiring president of the Association. There was a round-table introduction and short speeches by several members.

The regular program of the Society began promptly at 2:00 P.M. and the following papers were presented to a good attendance:

1. Ostracodes of the Arbuckle Limestone of Oklahoma. *R. W. Harris*
2. Faunal Zones in the Pre-Pennsylvanian of Oklahoma. *Ira H. Cram*
3. The Stock of *Triticites ventricosus* (Meek and Hayden). *Charles Ryniker*
4. Some Fusulinid Problems. *M. P. White*
5. Basis of Classification of Bryozoa. *R. C. Moore*
6. Basis of Classification of Ostracodes. *Betty Kellett Nadeau*
7. Nature and Distribution of the Hunton Formation in Kansas. *Olive Hoffman*
8. The Missouri-Virgil Boundary in Kansas. *N. D. Newell*

The program session was adjourned at 4:00 P.M. and the Society went into the annual business session.

1. Minutes of the 1934 meeting, published in the *Journal of Paleontology*, were approved.

2. *Report of the President.*—President N. L. Thomas did not make a formal report, but spoke briefly of his efforts to bring about a more united Society, secure new members, and otherwise promote the interests of the Society. He thanked members of the Society for their hearty cooperation. Members were reminded that a mail vote on permanent joint publication with the Paleontological Society would be called for about September. Attention of the membership was also called to the fact that too few papers from commercial workers are being offered to the editors for publication in the Journals. The President then called for reports of the Secretary-Treasurer and the Editor.

3. *Report of the Secretary-Treasurer.*—Gayle Scott, Secretary-Treasurer, expressed appreciation for the hearty support and cooperation of the membership, and noted that during the past few months his office had been primarily concerned with launching the business end of the new joint publication plan. He called attention to the excellent cooperation in these efforts between the officers of the Paleontological Society and the Society of Economic Paleontologists and Mineralogists.

The audit of funds of the Society was made as of January, 1935, instead of March 15, as in previous years. This was done at request of the officers of the Association and the audit is published in the March number of the Bulletin of the American Association of Petroleum Geologists.

The Secretary then read the following report:

The membership of the Society of Economic Paleontologists and Mineralogists on March 15, 1935, numbered 192 active members and 63 associate members. Dues for 1935 were collected January 1st, 1935. During the year, March 15, 1934, to March 15, 1935, the

Society elected 14 new active members and 12 new associate members. Applications now pending number 19.

The Secretary has directed his energies toward maintaining and increasing the revenues of the Society through the sale of back numbers of the *Journal of Paleontology*. The total paid subscription list of Volume VIII of the *Journal of Paleontology* amounts to 487. The total paid circulation of the *Journal of Sedimentary Petrology*, Volume IV, amounts to 264. Circular letters and advertisements illustrating and describing the publications of the Society have been sent out to libraries, and laboratories, and to geologists and paleontologists. A number of letters have also been written to prospective advertisers soliciting business. The total advertising amounts to approximately six pages yielding $354.65 revenue. One page, advertising the publications of the American Association of Petroleum Geologists, is in exchange for an advertisement of publications of the Society in the *Bulletin*, and the one-sixth page advertisement of Max Weg is in exchange for a similar amount of space in *Der Geologie*.

Both volumes of the 1934 issues of the Journals were printed by the George Banta Publishing Company at Menasha, Wisconsin. The full-tone plates in the *Journal of Paleontology* were printed by the Meriden Gravure Company at Meriden, Connecticut.

Altogether, Volume VIII of the *Journal of Paleontology* contains 483 pages, 59 plates, and was printed in lots of 1,000 at a total cost of $3,298.47. Volume IV of the *Journal of Sedimentary Petrology* contains 153 pages, 4 plates, and was printed in lots of 600 at a cost of $855.48.

The Society received several grants-in-aid this year: $354.00 (A.A.P.G.), $750.00 (National Academy of Sciences), $150.00 (National Research Council, to be used on publication of the *Journal of Sedimentary Petrology*).

The present financial status of the Society is satisfactory as shown by the following statement:

(Supplement to Cash Audit of January 1, 1935)

Cash on hand Jan. 1, 1935. (This includes the Savings Account of $2,681.96)	$3,347.24
Receipts from Jan. 1 to Mar. 15, 1935	2,215.25
	$5,562.49
Expenditures from Jan. 1 to March 15, 1935	1,110.49
Total amount of cash on hand	$4,452.00

It was moved by C. E. Decker and seconded by C. I. Alexander that the report be accepted. The motion carried.

4. *Report of the Editor.*—Raymond C. Moore, Editor, called attention to the fact that the *Journal of Paleontology* constituted his report. He emphasized the value to both organizations of the joint publication program.

It was moved by C. E. Decker and seconded by R. W. Harris that the report of the Editor be accepted. The motion carried.

5. Upon call of President Thomas, the Secretary read the following resolution, signed by 36 members of the Society, brought before the meeting by M. C. Israelsky, and previously reviewed by the Council in regular meeting:

We hereby petition the council of the S. E. P. M. to take steps to change the method of election of national officers from a vote at the annual meeting to mailed balloting in order that members not able to attend may be able to cast their vote.

In accordance with the suggestion of this petition the Secretary then read and moved adoption of the following revision of Sections 1 and 2 of Article II of the by-laws. The amendment, it was understood, should be in the nature of a temporary provision until such a time as a committee appointed by the President could propose a revision of the Constitution as to election of officers.

Art. II. Sec. 1. The nominations for each office of the Society shall be made by taking the two names receiving the highest number of

votes on a nominating ballot to be sent out to each member of the Society not less than five months preceding the annual convention. The returned ballots received by the Secretary within sixty days to be canvassed by him, and the ballots submitted to the Council for recanvass if requested. In addition to the nominations made by mail ballot the Council is instructed to submit one additional nominee for each office.

Art. II. Sec. 2. The officers shall be elected by mail ballot before the annual meeting of the Society. A plurality vote of the members for any candidate constitutes election.

The motion was seconded by M. C. Israelsky and carried by an apparently unanimous vote.

6. R. C. Moore then moved that the President appoint a committee to draft a revision of the Constitution and By-laws. R. W. Harris seconded the motion, and it was carried. In accordance with this action the President appointed the following Committee: Gayle Scott (chairman), F. B. Plummer, R. C. Moore, U. S. Grant IV, Jerry Upp, John E. Adams, Alva C. Ellisor.

7. The Secretary then brought up the question of reinstatement of delinquent members and moved that the Society adopt a plan similar to that of the Association. This may be done by approving the following addition to the By-laws:

In the case of any member or associate who has been dropped between the dates of January 1, 1931, and January 1, 1936, for nonpayment of dues and who shall apply for reinstatement, the Executive Committee is authorized, in its discretion, to accept the resignation of such member or associate effective at any date during such period of delinquency provided the member shall pay all indebtedness to the Association incurred prior to the date of such resignation including a proper proportion of annual dues as shall be fixed by the Executive Committee. Such member or associate shall not be entitled to receive the Bulletin for any period subsequent to the date when his resignation became effective and prior to his reinstatement.

It was moved by Gayle Scott and seconded by Jerry Upp that this provision be included as Art. I, Sec. 7, of the By-laws. The motion carried.

8. The President then appointed Betty Kellett Nadeau (chairman) and Katherine T. Pfannkuche as a Resolutions Committee.

9. *Election of Officers.*—Upon call by the President the Secretary then posted the nominations for the offices of the Society, as follows: President: W. H. Twenhofel, M. C. Israelsky; Vice-President: F. W. Rolshausen, U. S. Grant, H. L. Driver; Secretary-Treasurer: Gayle Scott, F. W. Rolshausen, M. C. Israelsky; Editor: R. C. Moore, J. B. Knight, M. A. Hanna.

The following officers were elected:
W. H. Twenhofel, President
U. S. Grant, Vice-President
Gayle Scott, Secretary-Treasurer
Raymond C. Moore, Editor

10. The meeting was adjourned until Saturday morning.

Saturday, March 23rd.

11. The Saturday morning session convened at 10:00 A.M. and papers 9–20, as listed below, were presented. Adams, Decker, Israelsky, and President Thomas presided in turn.

9. Sediment Types. *A. L. Lugn*
10. Studies on the Sediments of the Pennsylvanian of Iowa. *A. C. Tester*
11. Some Results of an Insoluble Residue Study of the Pennsylvanian of Nebraska. *E. C. Reed*
12. Insoluble Residues from Paleozoic Limestones of the Mosquito Range, Colorado. *Q. D. Singewald and Charles M. Reed*
13. Stratigraphy of the Midway (Eocene) of Southwest Arkansas and Northwest Louisiana. *C. I. Alexander*
14. Additional Midway Microfossils from the Gulf Coast of the United States. *Marion Setzer*
15. The Role of Diatoms in the Texas Tertiary Subsurface Stratigraphy. (Read by title). *M. M. Kornfeld*
16. Conodont Assemblages from the Nowata Shale. *Dan J. Jones*

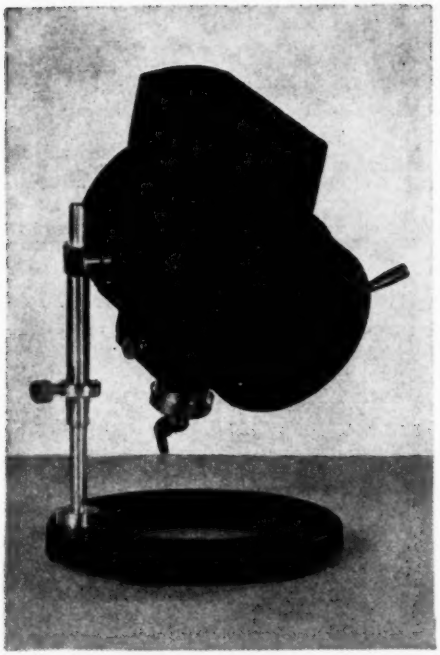
17. Probable Depth of Deposition of Big Blue Sediments in Kansas. *M. K. Elias*
18. Tertiary and Quarternary Proboscideans of Oklahoma. (Read by title). *J. W. Stovall, W. S. Strain, J. B. Wharton, J. T. Self.*
19. Tertiary Horses at Optima. (Read by title). *J. W. Stovall*
20. A Calcareous Alga in Upper Pennsylvanian of Kansas. *H. H. Hawkins*

At the end of the program President Thomas called for the report of the Resolutions Committee, and the following resolutions were read by the Chairman.

The Society wishes to thank the Kansas Geological Society, the Wichita Geological Committees and Mr. Jerry Upp, chairman of the arrangements, for the Paleontological group, for their splendid work in making the very complete arrangements for a most pleasant and constructive meeting.

C. I. Alexander moved that the report be accepted. The motion was seconded and carried.

The meeting was adjourned.



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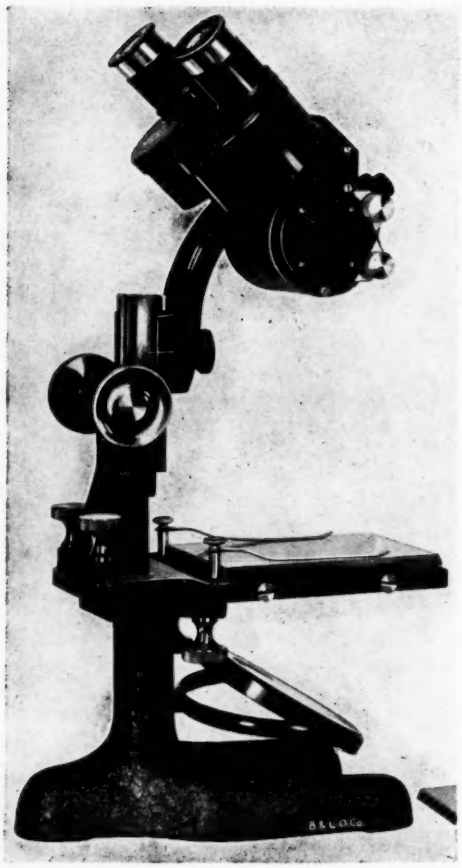

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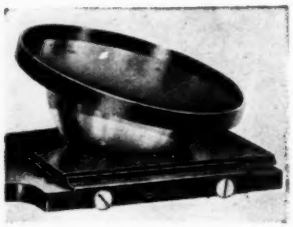

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